DISSERTATION

UNDERSTANDING PRO-ENVIRONMENTAL BEHAVIOR AND IMPROVING SOCIAL NETWORK RESEARCH METHODS TO INFORM CONSERVATION MANAGEMENT

Submitted by

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ABSTRACT

UNDERSTANDING PRO-ENVIRONMENTAL BEHAVIOR AND IMPROVING SOCIAL NETWORK RESEARCH METHODS TO INFORM CONSERVATION MANAGEMENT

Conservation issues exist in the context of social-ecological systems, with human activities driving threats to species, habitats, and important ecosystem functions. The successes and failures of conservation efforts depend on how humans behave. Likewise, human behavior is crucial to rectifying these problems. Understanding why humans behave in ways that help or hinder conservation efforts is vital to effectively manage and prevent threats to natural resources, such as invasive species. Research specific to each social-ecological context on how social networks, knowledge, and other cultural and social psychological factors influence behavior is needed to inform management decisions. In addition, effective and efficient social science methods are needed for practitioners to assess relevant behaviors more easily. This dissertation contributes evidence that advances our understanding of pro-environmental behaviors that help control invasive lionfish (*Pterois volitans*) in Belize and Florida and provides insights into data collection methods on social networks. Each manuscript assesses factors that influence a specific target behavior.

The first manuscript (Chapter 2) explores what factors affect consumption of the venomous, but edible, invasive lionfish in Belize. To determine the viability of a lionfish market in Belize, a national study of Belizeans (n = 400) and foreign tourists (n = 400) was implemented using structured surveys that assessed consumers' willingness to try lionfish, knowledge about lionfish, attitudes toward purchasing lionfish, and fear of trying new foods, or food neophobia. Findings show that most Belizeans and foreign tourists are willing to eat lionfish given the opportunity, but that a misperception that lionfish is not safe to eat and availability are barriers to eating lionfish. Belizeans, though concerned about lionfish, are less willing to consume lionfish than tourists and more likely to believe lionfish are unsafe to eat. In addition,

when asked why they would not eat lionfish, the most common reasons Belizeans described were related to perceived danger or preference. These and other findings about consumer behavior toward seafood in Belize, such as that Belizeans primarily choose to eat seafood for health reasons and prefer snapper to other types of seafood, provide important insights into opportunities to grow demand for lionfish and decrease barriers related to risk perceptions.

The second manuscript (Chapter 3) shares findings from a mixed methods study to understand how motivation and social capital affect removal of lionfish in Florida by spearfishers who hunt lionfish, or lionfish hunters. Findings are shared from semi-structured interviews ($N = 75$) as well as an online structured survey of 186 lionfish hunters. Results show that lionfish hunters who are motivated by money kill more lionfish than those motivated by other reasons. However, this group is very small in number and is sensitive to decreased lionfish numbers because it is prohibitive to commercial spearfishers' ability to profit from them. In addition, lionfish hunters who have a social contact who helps them sell lionfish kill more lionfish. However, this is still a small group. Most lionfish hunters in Florida are motivated to kill lionfish to protect Florida's reefs, to eat lionfish, and because it's fun. In addition, most feel an obligation or duty to kill lionfish in order to protect the reefs. Effective management strategies, therefore, should engage lionfish hunters across motivations to maintain consistent and long-term control of the population. In addition, practitioners should continue to cultivate a community around lionfish removal to better support money-motivated lionfish hunters' efforts to sell lionfish.

The third manuscript (Chapter 4) investigates the efficacy of including an example social network map in an online structured survey to increase responses to questions about social network contacts. Social network research can be inhibited by willingness of respondents to provide names and contact information of themselves and their acquaintances. For social network research to be more feasible among practitioners in the conservation field and beyond, effective methods for collecting this type of information are essential. This experimental study compared responses ($N = 186$) to social network questions between those who completed a survey with an example social network map versus a survey without a map. Results show that the example map did not increase provision of network contacts and did

not influence the types of ties reported. Therefore, while a map may not help in collecting more data, if it is necessary to include for explanatory purposes in a social network survey, it likely will not bias responses. Resistance among respondents to providing this information in this study demonstrate the need for further exploration into effective social network data collection methods for large groups, especially when snowball sampling is necessary.

ACKNOWLEDGEMENTS

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To my family and friends: you deserve honorary PhDs. My loved ones have listened to me talk about lionfish and social networks for what must be hundreds of hours at this point. To Kyle, my partner, thank you for your constant encouragement and for believing in me when I don't believe in myself. To my parents, Tara and Charlie Clements, thank you is not enough. Not only have my parents been by my side every step of the way but they have become experts on lionfish themselves. They have gone on road trips and attended tournaments with (and without) me throughout Florida, gotten SCUBA certified and searched for lionfish with me, provided their home in Miami as my field station, and even learned to expertly craft lionfish jewelry. I cannot imagine a more dedicated support system.

To the lionfish community: you are what inspired my dissertation topic. The lionfish community is a unique and passionate group of adventurers, researchers, conservationists, fishers, divers and ocean lovers who immediately welcome you into their family. Thank you to the hundreds of lionfish hunters who participated in my study. Thank you for teaching me to SCUBA dive, for answering my thousands of questions, for inviting me to lionfish tastings and celebrations, and most of all, for hunting lionfish!

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CHAPTER 1: INTRODUCTION

The vast majority of threats to nature across the globe originate from human actions. Conservation, therefore, is almost certain to fail without attention to human behavior and research on how to encourage modification of behavior. In fact, in "Conservation means behavior", Wesley Schultz (2011) proposes that "conservation is a goal that can *only* be achieved by changing behavior" (p. 1080). If human behavior is the primary cause of the destruction of the environment, then changing that behavior is the only way to mediate or prevent our impact. By identifying what drives various behaviors, we can implement effective message framing for behavioral interventions by appealing, for example to norms or by knowing your audience and relating to what matters to them (Kusmanoff et al. 2020). It follows, then, that the conservation community needs innovative and thoughtful research on behavior to be most effective. Creating behavior change is difficult, so the more we know about why people behave the way they do, the more successful conservation efforts will be. My dissertation investigates factors influencing pro-environmental behaviors that support invasive lionfish (*Pterois volitans*) control in Belize and Florida as well as behavior of respondents in answering an online survey that assessed social networks and pro-environmental behavior related to lionfish removal.

Understanding pro-environmental behavior

Previous research has warranted important findings regarding conservation behavior. Schultz (2011) describes several primary challenges and opportunities: education and information usually does not result in conservation behavior change; humans are biased in their thinking and do not respond rationally to environmental threats; humans tend to see themselves as separate from nature; social norms guide behavior; and motivation is the primary force driving behavior change. Oftentimes, in practice, interventions depend on the assumption that if people simply knew how their actions impact the environment, then they would adjust their behavior. Since research has clearly demonstrated that this is not the case, it is important to focus on what mechanisms do influence behavior and what barriers prevent desired behaviors.

Early models about pro-environmental behavior assumed that environmental knowledge leads to change in environmental attitude, which leads to change in behavior. However, these assumptions were proven to be flawed; increased knowledge does not necessarily lead to pro-environmental behavior (Kollmuss & Agyeman, 2002). Furthermore, environmental attitudes do not necessarily lead to pro-environmental behavior. To more effectively predict a behavior, we should measure attitudes toward that specific behavior (Ajzen & Fishbein, 1980). Other models focus on altruism, empathy, and prosocial behavior to understand pro-environmental behavior, with the expectation that people who are more selfish and competitive are less likely to exhibit pro-environmental behavior and those who have satisfied their own needs and have the capacity to care about social and environmental issues are more likely to act pro-environmentally (Borden & Fancis, 1978; Kollmuss & Agyeman, 2002). Stern et al.'s (1993) model postulates that motivation is a combination of egoistic orientation (relieving one's own suffering), social orientation (relieving other people's suffering), and biospheric orientation (removing suffering in the natural or non-human world), with egoistic being the strongest motivating orientation. In other words, a person will be more likely to perform a pro-environmental behavior if the behavior also helps them. Altruistic behavior is also activated by personal norms and feeling a moral obligation to act in a prosocial manner (Schwartz, 1977). Other factors that drive pro-environmental behavior include demographic, institutional, economic, social, and cultural norms, as well as motivation, values, emotional investment and locus of control (Kollmuss & Agyeman, 2002).

Factors most relevant to the studies presented in this dissertation include attitudes toward a behavior, knowledge, fear of trying something new (neophobia), motivation, and personal norms. These factors were chosen based on the contexts and applied questions in each study site that are most relevant for management of invasive lionfish. In addition to measuring determinants of behaviors, these studies measured actual behaviors, which is an approach encouraged by Nilsson, Fielding and Dean (2019) for improved research on and clearer understanding of pro-environmental behaviors.

More than sixty theories have been developed for understanding determinants of behavior, and many can be or have been applied to invasive species management (McLeod et al., 2015). For example, in Hawai'i, Kalnicky, Brunson and Beard (2019) applied the Theory of Planned Behavior to assess the role of attitudes, behavioral intentions, and subjective norms in property owners' management of an invasive frog (*Eleutherodactylus coqui*). Research on and management of aquatic invasives often focuses on preventing spread of species by boaters and has investigated the role of value orientations and attitudes in responsible boating behavior (Pradhananga et al., 2015), Determining the most relevant research questions and what behavioral drivers to investigate for invasive species management depends on the specific context (McLeod et al. 2015). For example, a study in British Columbia, Canada found that natural place attachment, but not civic attachment predicts various pro-environmental behaviors (Scannell & Gifford, 2011); however, Niemiec et al. (2017) found that civic, but not natural place attachment predicted residents' behaviors to control the invasive *Albizia* tree in Hawai'i. This difference was likely due to the context of these residents' behaviors and that the tree poses hazardous threats to residents' and the community's well-being when tropical storms cause them to fall onto roads, powerlines, and buildings.

Some invasive species control efforts require involvement of recreationists to help prevent the spread of aquatic invasive species. When invasive species cause damage to species or habitats that recreationists value, it typically motivates these stakeholders to take action (Sinclair et al., 2020). In a study on recreationists' awareness of various aquatic invasive species, Seekamp et al. (2016) found boater-anglers were most aware, knowledgeable of aquatic invasive species, and felt the most personal responsibility for their control. Another study on recreationists' behaviors to reduce the spread of invasive species identified important barriers to these behaviors due to certain attitudes, norm beliefs, and behavioral control beliefs (Prinbeck, Lach & Chan, 2011). However, there is a gap in behavioral research on recreationists' harvest behaviors of invasive species, despite various contexts in which invasive species have become popular among hunters and fishers, such as feral pigs (*Sus scrofa*) in Hawai'i (Pejchar &

Mooney, 2009), which has become a source of conflict due to a mixture of benefits and trade-offs they provide to human well-being. Sinclair et al. (2020) categorize invasion processes into various reciprocal feedback processes. They describe recipient region positive feedback loops as instances in which the invasive species becomes more positively perceived and even desirable in the invaded region, causing proliferation rather than suppression of the species. On the other hand, efforts by recreationists and other stakeholders in the invaded region to protect the natural system and native species they depend on by taking action to prevent the spread of the invasion creates a negative feedback loop. The key difference between these two scenarios is the perceptions and motivations of the people in the recipient region. The way an invasive species is described in a recipient region influences how people perceive the species in terms of risk and ecological impacts, which in turn affects people's willingness to take action to control the invasion (Hart & Larson, 2014). Thus, in contexts where the benefits of invasive species, such as feral pigs, help motivate removal, these benefits must be balanced with continued framing of the invasive as detrimental. The focus of this dissertation is an invasive species, the invasive lionfish, which people attain benefits from through recreational and commercial spearfishing and consumption, but which is perceived as a threat to ecosystem, thus motivating action to suppress it. What factors influence consumption and removal of lionfish and what motivates people to remove lionfish will determine what type of feedback loop, positive or negative, exists in the invaded region.

Pro-environmental behavior and invasive lionfish control

My dissertation investigates pro-environmental behaviors related to invasive lionfish control in Belize and Florida. I use a systems approach to identify what human behaviors are most important for successful management of lionfish. Frameworks for studying social-ecological systems (SES), or coupled human and natural systems (CHANS), resonate throughout the conservation field. SES frameworks, such as adaptation, resilience, or Ostrom's SES Framework, strive to recognize human-environment connectivity in order to address humanitarian and sustainability issues (Berkes & Folke, 1998; Nelson, Adger & Brown, 2007; Ostrom, 2009). My research is guided by a CHANS approach, which evolved

from previous SES frameworks, and which recognizes that human and natural domains are not separate but connected entities that require integration of social and ecological sciences to understand (Liu et al., 2007).

Invasive lionfish have rapidly grown in number in the Caribbean region and West Atlantic (Côté, Green, & Hixon, 2013) since their first documented appearance in the Atlantic in 1985. They were likely introduced through release or escapes from marine aquaria (Hare & Whitfield, 2003). Lionfish threaten native reefs by predating and competing with native species (Albins & Hixon, 2008). Lionfish are excellent invaders. Not only are they venomous and cryptic in appearance, but they also thrive in a variety of habitats and spawn multiple times per month throughout the year, with annual fecundity estimated at more than two million eggs per female (Morris & Whitfield, 2009). Although eradication is unlikely, culling has been found to reduce lionfish and increase native fish densities at targeted sites (Green et al., 2014).

Consumption of lionfish in Belize

Although lionfish are venomous, they are an edible and desirable seafood product, with firm mild, flesh comparable to grouper or hogfish (Chapman et al., 2016; Chapman et al., 2019). In Belize, a lionfish market has been identified as a key strategy for lionfish control but ensuring that fishers are able to sell their lionfish is important to encourage continued removal and to protect their livelihoods (Chapman et al., 2019). The Belize National Lionfish Management Strategy, 2019-2023 provides a CHANS framework specific to invasive lionfish in Belize from which to build on (Chapman et al., 2019). A simplified version of the framework is shown in Figure 1.1.

As shown in Figure 1.1, lionfish catch directly affects lionfish population, with lionfish markets serving as a driver of lionfish catch. To determine the viability of a lionfish market to effectively control the invasion, demand for lionfish must be reliable, as fishers are willing to target lionfish if they know they can sell it (Chapman et al., 2019). A study of restauranteurs in Belize found that of those who had tried eating it, most indicated they liked it or loved it and most said they would eat lionfish in the place of

snapper or grouper (Chapman et al., 2019). However, some restaurants indicated barriers to serving lionfish include accessing a regular supply and that it is often a special rather than a permanent addition to

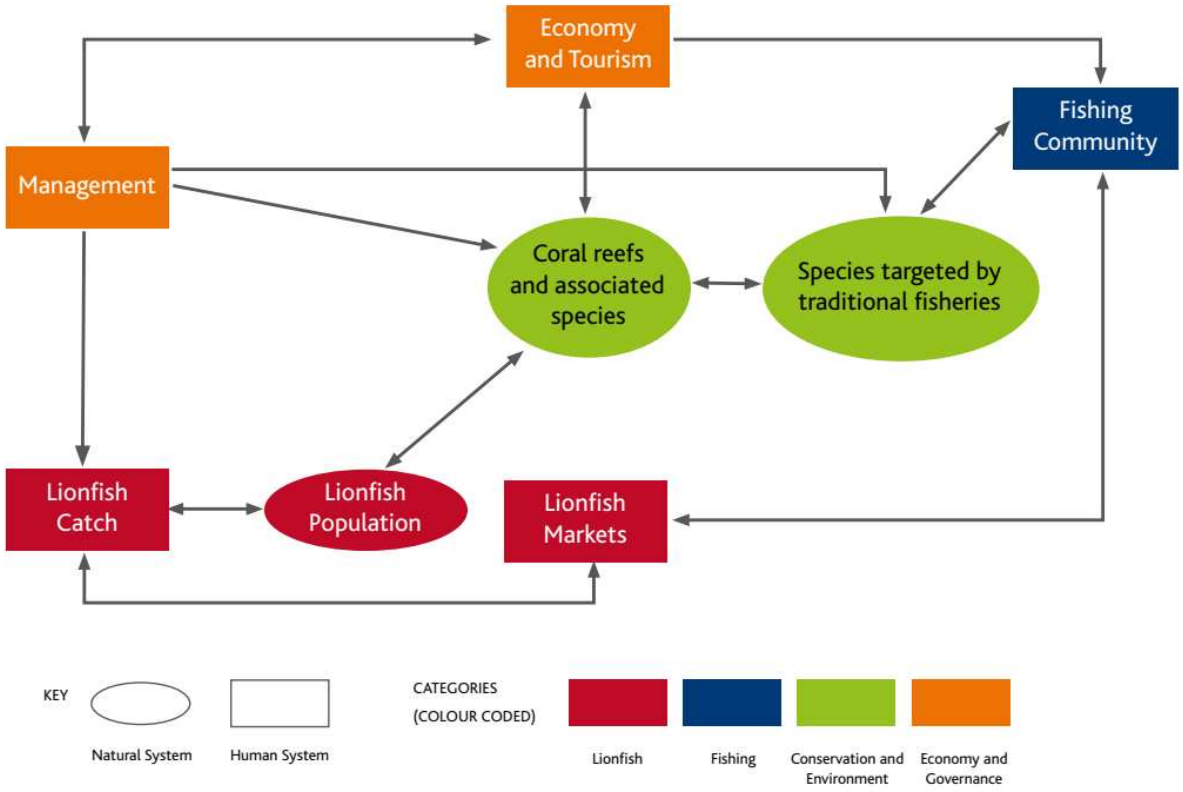


Figure 1.1 Simplified socioecological framework describing interactions between human and natural systems associated with lionfish management in Belize (Chapman et al., 2019)

the menu. These findings represent a small subset of consumptive behavior in Belize, however. A national assessment of foreign tourists' and Belizeans' consumption of lionfish in Belize and what determinants of and barriers to this behavior exist is the central research question of Chapter 2. A conceptual framework focused specifically on the lionfish market which provides the logical basis for Chapter 2 as it relates to the overall goal of lionfish control is shown in Figure 1.2. Lionfish catch by fishers and lionfish population affect each other because sufficient numbers of lionfish are necessary for fishers to harvest them, which in turn decreases the population. Similarly, sale of lionfish encourages lionfish catch by fishers, but sale is only possible given fishers catch lionfish to sell. Finally, sale of lionfish is dependent

on demand for lionfish, which is ultimately based on tourists' and Belizeans' consumption of lionfish and what influences this pro-environmental behavior.

Eating invasive species is not a new strategy for invasive species control. Other invaders that humans have attempted to suppress through consumption include Asian Carp (*Hypophthalmichthys*

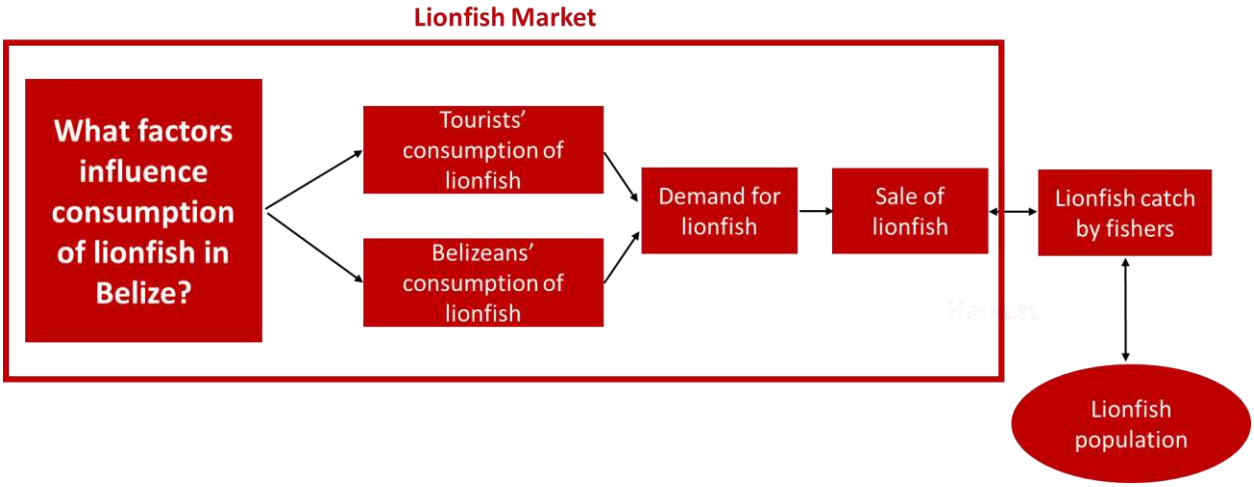


Figure 1.2 Conceptual framework outlining how the pro-environmental behavior of consuming lionfish is linked to control of the lionfish population in Belize

nobilis) in Illinois, nutria (*Myocastor coypus*) in Louisiana, and brown trout (*Salmo trutta*) in New Zealand (Nuñez et al., 2012). A study assessing consumers' willingness to try and willingness to pay for Asian Carp investigated willingness to pay for and willingness to try the fish as well as factors influencing each (Varble & Secchi, 2013). The study found that food neophobia, awareness of Asian Carp, and whether the fish was locally caught and processed significantly predicted willingness to try Asian Carp. This case study offers helpful insights for investigating similar questions about food neophobia and consumption of lionfish, especially considering that lionfish, though possibly more desirable in taste than Asian Carp, is also venomous.

Chapter 2 presents findings on how intrapersonal factors, including knowledge, attitudes toward purchasing lionfish, and food neophobia, predict consumers' willingness to try eating lionfish. In addition, this study explored what barriers exist to eating lionfish in Belize and seafood preferences and consumption more generally.

Removal of lionfish in Florida

While a CHANS framework has not been developed specifically for Florida as it has been for Belize, lionfish catch is still the primary means of control for the lionfish populations in Florida. However, the context surrounding fishers who remove lionfish in Florida, or lionfish hunters, are different. For one, the lionfish market in Florida is established, with lionfish sold in grocery stores, thanks to the efforts of key actors, including the Florida Fish and Wildlife Conservation Commission (FWC), Whole Foods, scientists, and divers, among others (Morris et al, 2008). However, communication and outreach efforts by these entities have been so successful that supply of lionfish cannot always meet the demand (S. Funck, M. Kennison, K. Spurgin, H. Tillotson, personal communication, February 1, 2019).

In addition, in Florida, both commercial and non-commercial spearfishers are involved in lionfish removal. For example, many divers are engaged in lionfish tournaments, cookoffs, and research and therefore do not always kill lionfish for commercial purposes. Lionfish tournaments are a common control strategy in Florida and are well-attended. The largest lionfish tournament in the world, the Emerald Coast Open, takes place in Destin, Florida, where 189 scuba divers removed more than 14,000 lionfish in two days in 2019 (Ulman et al., 2021). Lionfish removal in Florida and across the invaded range depends on these lionfish hunters to control lionfish because thus far we do not have a more efficient method for catching them (Ulman et al., 2021). However, because lionfish hunters in Florida appear to remove lionfish for both recreational and commercial reasons, the question remains: what motivates lionfish hunters to remove lionfish and who removes the most?

In addition, lionfish hunters in Florida tend to be connected to each other due to the nature of diving (it requires multiple people and usually involves a dive buddy), collaboration on teams (usually of 2-4 people) for tournaments or through engagement by various conservation organizations, which suggests that lionfish hunters' social networks may play a role in their removal activities. Social networks can help or inhibit pro-environmental behavior depending on how they affect access to social capital (Cho & Kang, 2017). According to Lin, Fu, and Hsung (2001) social capital contains three ingredients:

resources embedded in a social structure; accessibility to these social resources by individuals; and use or mobilization of them by individuals engaged in purposive action (p.58).

Access to certain resources, such as a boat, or information about where to find lionfish, may depend on a lionfish hunters' relationships with people who serve as resource brokers of such capital. An example of this from social network research on communities demonstrates how resource brokers provide access to important contacts and services. Small (2006) found that local organizations help provide access to daycare in poor neighborhoods in New York City. In the study, although neighbors could find day-to-day support from intimate ties such as kin or neighbors, their access to other important resources such as childcare came from networks of community organizations. A similar dynamic may be true for lionfish hunters and how they share information, resources, and knowledge related to lionfish removal. Chapter 3 assesses what types of relationships lionfish hunters have with each other and which of these enable removal of more lionfish. This mixed methods study comprises semi-structured interviews (n = 75) and an online structured survey (n = 186) of lionfish hunters who remove lionfish in Florida.

Social network research and pro-environmental behavior

Social network theory attempts to explain how people, organizations, or groups interact with others inside their network. A social network is a patterned set of relationships among two or more actors. Social network research helps us understand individuals in the context of their community and often provides important insights into human behavior. For example, in a study on building occupants and their social networks, Chen, Taylor, and Wei, (2012) found that information exchange through the overall network influenced individuals' pro-environmental behaviors. This study, which employed agent-based modeling to depict peer networks within a building and to predict the spread of behavior change through the network, also found that Individuals with stronger ties rather than many ties were more influential in affecting peer behavior. Natural resource governance researchers have found utility in studying social networks and how different structures and relationships support or hinder governance systems. Bodin and Crona (2009), for example, outlined the benefit of core-periphery networks, in which core actors are

densely tied, or centralized, and peripheral actors are connected only to these core actors, who have more political contacts. In the case studies Bodin and Crona (2009) analyzed, this type of network was ideal because it facilitated access to diverse knowledge and mobilization of support at key moments in the governance process.

A particularly relevant example is a study done on shark bycatch in a commercial tuna fishery in Hawai'i, which conducted a survey and social network analysis in which researchers asked participants about their interactions with other fishers (Barnes et al., 2016). Findings indicated that social networks influence actions that can directly impact marine ecosystems. For example, biases within smaller groups, such as a preference to spend time with people who are similar to yourself, can prevent diffusion (or spread) of sustainable behaviors. In other words, if new information or a behavior does not reach someone within your group, then you do not learn about it or adopt it. Through SNA, the study identified communication channels that bridged these gaps among fishers. Their analysis suggested that "enhanced communication channels across segregated fisher groups could have prevented the incidental catch of over 46,000 sharks between 2008 and 2012 in a single commercial fisher" (Barnes et al, 2016).

Understanding the social dynamics within a network begins with SNA, which is a method for assessing patterns of social interactions and social support between network members by identifying key relationships. However, SNA is only possible when enough data on the social network is collected, usually between 70% and 80% of the network in question (De Brún and McAuliffe 2018). This means that when this is done through surveys and questionnaires, which is often the case (O'Malley and Marsden 2008), respondents must provide personal information about themselves and others, including names and contact information. In fact, the study described in Chapter 3 attempted to collect data on the whole network of lionfish hunters in Florida, but the response rate to the survey or its social network questions was too low to capture at least 70% of the network. Because these types of data collection tools can be burdensome and requires sharing of personally identifying information, methods for encouraging respondents to share this information are needed so that social network research can be successful. My

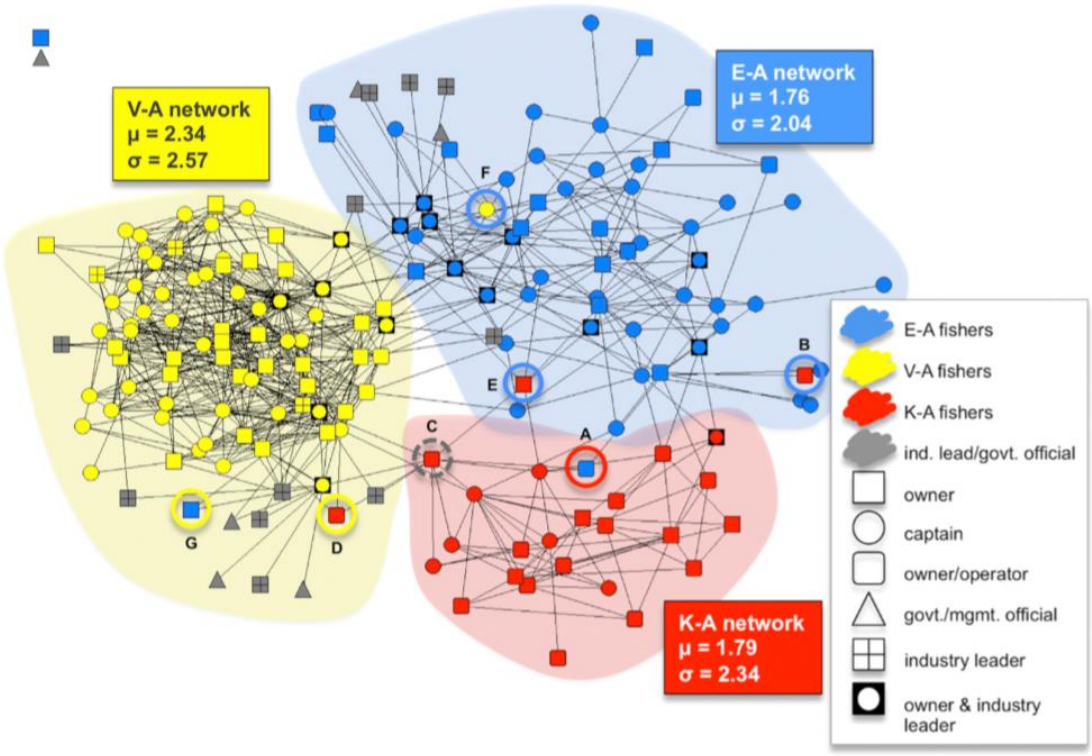


Figure 1.3 Social network map of fishers from a study of shark bycatch (Barnes et al., 2016)

dissertation includes a novel experimental study (Chapter 4) investigating this data collection challenge and whether providing an example social network map in an online survey of lionfish hunters increases their responses to social network questions.

CHAPTER 2: BARRIERS AND OPPORTUNITIES FOR CONSUMPTION OF LIONFISH IN BELIZE

Chapter Summary

Invasive lionfish (*Pterois volitans*) have rapidly increased in number in Belize since first documented in 2008. They reproduce frequently and consume native fish that are important to reef health and human livelihoods. To combat the deleterious impacts of this species, management efforts in Belize have focused on development of a market for lionfish. To determine the viability of a lionfish market and marketing strategies to sell lionfish in Belize, we conducted nationwide, structured surveys with a representative sample of Belizean residents (n = 400) and foreign tourists (n = 400). We assessed knowledge about lionfish, attitudes toward purchasing lionfish, and food neophobia (fear of trying new food) to predict the behavior of consuming lionfish and compared the two groups across each variable. We found no significant difference in awareness or knowledge of lionfish between Belizeans and tourists. However, tourists were more willing to try lionfish and have significantly less food neophobia than Belizeans. Belizeans were more likely to believe lionfish meat is unsafe to eat, which had a significant negative effect on their willingness to try it. Seafood consumption and preferences were also measured. Taste and health were identified as the most common reasons that both groups chose to eat seafood, though health was noted more often by Belizeans, and tourists often stated that they choose seafood because it is fresh and available locally. These findings offer evidence supporting the viability of marketing lionfish to Belizeans and tourists and provide insights for effective messaging.

Introduction

Invasive lionfish in Belize

First documented in the Atlantic Ocean in 1985 and in Belize in 2008, invasive red lionfish *Pterois volitans* (Linnaeus 1758) have rapidly grown in number in the Caribbean region and West Atlantic (Côté, Green, & Hixon, 2013). Lionfish become sexually mature within a year, reproduce

frequently, and consume the young of native fish important for coral reef health and fisheries (Côté et al., 2013; Morris, 2009; Zeller, Graham & Harper, 2011). They consume enough small native fish to decrease numbers by 95% in some sites (Côté et al., 2013) and have no predators in invaded regions (Hackerott et al., 2013). The lionfish invasion has been deemed one of conservation's greatest contemporary challenges (Sutherland et al. 2010).

According to the Food and Agriculture Organization of the United Nations (FAO, 2019), fisheries make up approximately 3% of Belize's GDP. In 2017, 2,716 fisher folk licenses were issued (FAO, 2019); in 2016, exports of fish and fishery products were USD 15.6 million. Most finfish landed is sold locally and consumed by Belizeans and tourist visitors (FAO, 2019). Fish is an important contribution to food security for Belizean households. Fish and chicken are the main sources of animal protein throughout Belize and fishing traditionally has been a source of subsistence in coastal communities (FAO, 2019). Thus, outside of GDP and livelihoods, healthy fisheries play an important role in providing food to Belizeans.

Impacts of lionfish are important to other sectors of Belize's economy as well. The second largest barrier reef, the Mesoamerican reef, spans Belize's coastal border. In 2018, travel and tourism contributed to 44.9 % of GDP (an increase from 22.4 % in 1999) (Belize Tourism Board, 2018). A nationwide survey conducted in 2018 by the Belize Tourism Board in airports found that 57.8% of tourists intended to visit the barrier reef. The next most common activities included visiting marine protected areas (46.6%), offshore islands (45.0%), and a national park or reserve (41.7%). Thus, lionfish pose a direct threat not only to the livelihoods and food supply of fishers and their families but also to tourism, which relies on Belize's healthy marine ecosystems.

Solutions to the invasion

Eradication of lionfish in their invasive range is highly unlikely, but persistent site-specific culling allows native species to rebound to sustainable levels (Côté et al., 2014). Efforts in Belize and

elsewhere in the Caribbean focus on human consumption of lionfish (Chapman et al. 2016; Peiffer et al., 2017). In these and other invaded areas, additional strategies include tournaments, tastings, outreach events and others to combat the invasion. While tournaments can be effective at certain sites by removing large quantities of fish at one time other sites require long-term, consistent removal to suppress lionfish numbers enough to protect reefs and native species (Green, Underwood, & Akins, 2017). A lionfish market may ensure such consistent, long-term removal.

Belize is the first country to take a coupled human and natural systems (CHANS) approach to inform invasive lionfish management (Chapman et al., 2019). Belize's lionfish management strategy aims to suppress lionfish populations below levels that affect native species and to create new socioeconomic benefits through lionfish control efforts. Based on scenario planning research that informed the management plan, a domestic lionfish fishery was determined to be the most strategic management approach for lionfish control outside of protected areas. Chapman et al. (2019) conducted surveys with fishers and restaurant managers to identify barriers to market growth. While restaurant managers indicated that irregular lionfish supply was the primary barrier to serving it in their restaurant, fishers spoke of an inconsistent lionfish demand: ""If there was a constant sale for lionfish I would capture more. Sometime fishermen capture lionfish and cannot sell it because there is no one interested in buying it." (F6, Sarteneja)". Consumer demand for lionfish in Belize is central to the viability of a lionfish market.

Knowledge, attitudes, food neophobia and behavior

Demand for lionfish depends on various factors, namely whether consumers in Belize are willing to eat it. Research on pro-environmental behavior shows that knowledge is an important basis for behavior, but that attitudes and behavioral intentions play a mediating role between knowledge and behavior (Liu, Teng & Han, 2020). Based on the Theory of Planned Behavior, attitude toward a specific behavior (i.e. I would like to recycle) is also a better predictor of behavior than more general attitudes, (i.e. I care about the environment) (Ajzen, 1991). This has been applied to food consumption behaviors as well (Ajzen, 2015). Consumers' knowledge about lionfish, such as that it is invasive and is safe to eat,

and attitudes related to purchasing lionfish likely influence whether they will consume it. In addition, consumers must be open to trying a new food, specifically an exotic, venomous fish.

Food neophobia is a person's willingness to try different, unique, or novel foods (Pliner & Hobden, 1992). While this trait, common among omnivores, is useful for protecting humans from accidentally eating harmful foods, it can also create barriers to marketing sustainable, but unfamiliar, foods (Pliner & Hobden, 1992). As similar research on a market-based approach to invasive Asian carp management has demonstrated, neophobia is an important factor in measuring, predicting, and influencing consumption of an untraditional food source, such as an invasive species (Varble, & Secchi, 2013). Another challenge in the case of Belize is the lack of existing research on food, and specifically seafood preferences, a gap in research that this study helps to fill.

Outside of a study by Pott (2010), which found that Belizeans struggle to have access to quality seafood, research on seafood preferences in Belize is lacking. However, lionfish-specific research has helped to characterize Belizeans' evaluations of the taste of lionfish. For example, in a study done in fishing communities in Belize, respondents compared the taste of lionfish to grouper (*Epinephelinae*) or hogfish (*Lachnolaimus maximus*), which are two of Belize's most popular and expensive fish (Chapman et al., 2016). Study participants who tasted lionfish were found overall to like its taste.

While lionfish may have taste on its side, consumption of them poses another major challenge in terms of food neophobia: perceived risk of envenomation. Lionfish have 18 venomous spines on their body (Morris et al, 2008); venom is contained in the tissue encasing the spine so that when the spine makes contact, it tears through the tissue, causing venom to enter the puncture wound. Injury to humans can be severe, causing swelling, extreme pain, and paralysis in the extremity that has been envenomated. Importantly, lionfish are not poisonous. A poisonous organism is one which injures you when it is inhaled, swallowed, or absorbed through the skin. A venomous organism injects the toxin into you. The portrayal of lionfish as a venomous, dangerous, or even poisonous (often confused with *venomous*) fish

may create a stigma of risk. This association may likely increase levels of food neophobia toward lionfish and requires effective communication to correct misperceptions.

Diffusion of innovation and adoption of behavior

Diffusion of innovation is a theory about the process of introduction of new innovations which are communicated through channels over time within a social system (Rogers, 2003). The curve itself, shown in Figure 1, has five categories: innovators, early adopters, early majority, late majority, and laggards, with the innovators adopting an idea or behavior the quickest and the laggards the slowest.

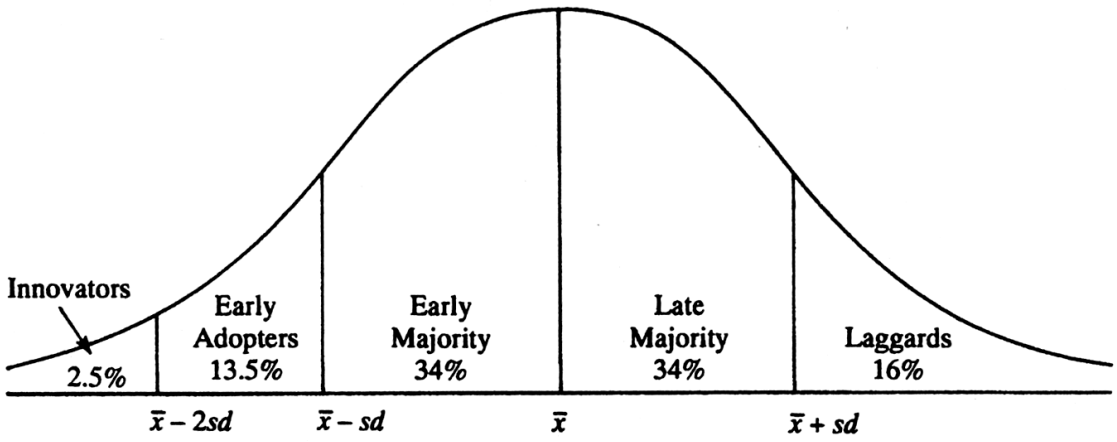


Figure 2.1 Diffusion of Innovations curve

Adopter categorization of innovativeness, partitioned into five categories based on standard deviations from the average time of adoption, with the innovators adopting an idea the quickest and the laggards adopting the slowest. Reprinted from Diffusion of Innovations (p. 281), by E. Rogers, 2003, New York, NY: The Free Press.

As shown in Figure 2.1, the majority of a given population tends to fall in the middle categories: early majority and late majority. Some literature suggests that progressing from the early adopter to early majority often poses a major roadblock in widespread adoption of a desired behavior (Moore, 2014). Therefore, an important question we address in this paper is where Belizeans and foreign tourists fall on the diffusion curve in adopting lionfish consumptive behavior and what barriers prevent additional consumers, and the early majority, from consuming lionfish.

Lionfish consumption

Consumers' willingness to consume lionfish in Belize is a central factor in determining whether there is a consistent market incentive for fishers to harvest lionfish. Ideally, the market would consist of both Belizeans and foreign tourists (hereafter, "tourists") consuming lionfish on a regular basis, with Belizeans serving as year-round consumers, and tourists supplementing demand. Prior to the research described in this paper, there was no nationwide research on knowledge, attitudes, or behaviors related to lionfish in Belize. Other research on lionfish consumption occurred in northern Belize fishing communities where awareness of the lionfish invasion among Belizeans was high (Chapman et al., 2016). Outreach efforts have been implemented in other parts of the country to extend this awareness. In 2012, research explored speculation that the greatest demand for lionfish may lay with tourists, while Belizeans may be unwilling to eat lionfish in place of other fish even when they liked the taste of the meat and were aware of the invasion (Chapman, 2013). However, data on a national scale was not available to confirm this and data on tourists' awareness of lionfish is lacking.

The present study is the first nationwide survey of lionfish consumption in Belize. The purpose of the study was threefold: to assess Belizeans' and tourists' willingness to consume lionfish, identify what factors prevent or predict consumption of lionfish, and determine how far along the diffusion of innovation curve both groups are in adopting the behavior of consuming lionfish. We specifically focused on how knowledge about lionfish, attitudes toward purchasing lionfish, and food neophobia affect whether consumers are willing to try lionfish. In addition, we assessed important practical questions such as how frequently and where seafood is consumed, what types of seafood are preferred, and where respondents first heard about lionfish. Of particular interest in this study is these two audiences' perceptions of and willingness to try lionfish despite its exotic and venomous characteristics.

Methods

Study site

Belize is a small country (8,867 mi^2) in Central America's Yucatan Peninsula bordered by Mexico, Guatemala, and the Caribbean Ocean (Griffith, Alford & Bolland, n.d.). Formerly a British Colony, Belize declared independence in 1981. English is the primary language spoken in Belize, but Creole and Spanish are common. According to The Statistical Institute of Belize, the estimated total population in 2017 was 385,766, split almost evenly between males and females (2017). The most common ethnic group Belizeans identify as is Mestizo/Hispanic (48%), followed by Creole (26%), Maya (11%), "Other" (10%), and Garifuna (5%) (The Statistical Institute of Belize, 2017). These data do not identify the population of East Indian Belizeans specifically, though may be encompassed by the other groups such as "Other".

Questionnaire design

The questionnaire was developed in collaboration with marine conservation practitioners in Belize involved in lionfish management and who are co-authors on this paper. The questionnaire included important practical questions for understanding behaviors related to seafood consumption and lionfish, and modeled similar questions asked in Varble & Secchi's (2013) study on Asian Carp consumption, such as "How often do you eat seafood" and "Have you ever tried eating lionfish?" as well as groups of questions, or scales, measuring knowledge, attitudes, and food neophobia. Knowledge about lionfish was measured based on a series of True or False statements, such as "Lionfish have always been in Belize's waters" and "Lionfish meat is safe to eat". Rather than measuring general attitudes about the environment or about lionfish, attitudes toward the desired behavior were measured, which is a better predictor of actual behavior (Ajzen & Fishbein, 1980). Attitudes toward the behavior of purchasing lionfish were measured using a Likert scale that included a series of statements specific to purchasing lionfish, such as "I would purchase lionfish if I knew that buying it had a benefit for the reef" and "I would purchase

lionfish if it was regularly available", with response options from 1, Strongly disagree, to 2, Strongly agree. Similarly, food neophobia was measured using the same response options to a series of statements, such as "I will eat almost anything" and "I do not trust new foods" based on Pliner and Hobden's food neophobia scale (1992). See Appendix B for the complete tourist questionnaire and Appendix C for the Belizean questionnaire.

Data collection

Five hundred and thirty-three Belizean residents were randomly sampled from across the nation. We sought to create a representative sample based on ethnicity and geographic location (see below for details), which resulted in a final *n* of 400. The structured survey measured attitudes, awareness, level of knowledge, and consumption rates of lionfish and other seafood. It was administered nationwide during the summer of 2015 to Belizean residents 18 years and older. A similar survey was administered in 2016 to foreign tourists; a sample of 400 tourists was chosen based on tourist visitation data, specifically number and location of foreign tourists, and designed to create a representative size. The surveys were conducted face-to-face in public areas such as open central market areas, public parks, and bus and water taxi terminals using iSurvey software on Apple iPads.

The survey of Belizean citizens was administered in English and Spanish, depending on the preferred language of the participant. Using the most recent census data available at the time of the survey (2010) we sampled individuals randomly in the six district capitals (Corozal Town, Orange Walk Town, Belize City, Belmopan, Dangriga Town and Punta Gorda Town) as well as all municipalities with a population of 6,000 or more individuals (San Pedro, Santa Elena, San Ignacio and Benque Viejo del Carmen) according to the 2010 census (Figure 2.2). Due to Santa Elena's proximity to San Ignacio, and its lack of optimal sampling locations, we doubled the number of respondents captured in San Ignacio to account for this discrepancy. Sampling locations were purposively chosen to find a representative sample of Belizean ethnic groups. Individuals were selected from passersby on an every-other, random basis. In the case of bus terminals, which experience a higher proportion of stationary activity, one individual was

Figure 2.2 Map of Belize study sites

Surveyed sites indicated by colored circles. Orange circles indicate locations where tourists were surveyed, blue where Belizeans were surveyed, and black where both were surveyed.

randomly asked to participate from each bench until all benches were surveyed; then the process was repeated. Prospective Belizean respondents were screened using two questions; “are you a resident of Belize? (greater than 1 year)” and “are you 18 years of age or older?”

The survey of foreign tourists in Belize was administered in English in San Pedro, Caye Caulker, Belize City, and Placencia (Figure 2.2) because these locations experience a high influx of foreign tourists. Respondents were again selected at random at public sites, such as water taxi terminals, markets, and beaches, that experience high tourist traffic. In comparison to the Belizean

survey instrument, some survey questions were modified to be more relevant and understandable for the foreign tourist population. However, only survey questions that were the same for both groups were compared using statistical analyses.

Data analysis

Responses were analyzed using Statistical Package for the Social Sciences (SPSS) software. Survey questions with dichotomous yes/no responses were analyzed using Crosstabs and Pearson Chi-square tests to measure significant difference, followed by a measure of *phi* to determine effect size. These tests were used for categorical questions about awareness of lionfish, experience trying lionfish, and willingness to try lionfish. Z-tests were used to compare Belizeans' and tourists' reasons for eating seafood, using Cohen's h to measure effect size. Categorical variables with more than two possible responses were analyzed using Crosstabs and Pearson Chi-square tests (this paper reports the Likelihood Ratio as χ^2), followed by a measure of Cramer's V to determine effect size. These included questions about reasons for eating seafood and, more specifically, reasons for consuming lionfish. Likert scale questions measuring attitudes toward lionfish, food neophobia, and knowledge were compared between groups using Mann-Whitney U Tests followed by η^2 for effect size. Finally, binary logistic regression analysis was used to measure correlations between variables and to explore what factors, including attitude, knowledge, neophobia, gender, and age predict willingness to try lionfish. In these regressions, respondents were grouped into those who said "yes" versus all other respondents, including "undecided" and missing responses, in order to focus on the specific desired behavior. Main effects and interaction effects models are reported in the results as well as scatterplots of moderating variables.

Results

Sociodemographics

Almost half of the Belizeans surveyed were Mestizo/Latino, most did not work in the tourism, fishing or restaurant sector, and most lived on the coast, many in Belize City (Appendix Table A1). In

comparison, a large majority of tourists identified as a diver or snorkeler and were visiting multiple coastal towns. In addition, the top four reasons tourists choose to visit Belize are because "It was recommended", for "Marine activities", "Travelling through/VISA stop", and "Nature and climate" (Appendix Figure A1).

Seafood consumption

Belizeans and tourists were asked a series of detailed questions about their seafood consumption, including frequency, and favored types of fish. A full report of responses to these questions is included in Appendix Table A2. When asked their first choice when eating seafood, 67% of Belizean respondents named snapper (*Lutjanidae*) as their favorite fish, with the next most popular fish chosen by only 4% of respondents. Of the tourists who eat seafood *and* said they would eat seafood every day or every other day while in Belize, 98% planned to visit one or more coastal towns. When asked "Why do you choose to eat seafood?", the most common response among Belizeans was health (37%), followed by taste (28%) and among tourists was taste (31%), followed by because it is fresh or local (30%), and health (17%). See a full summary of responses to this question in (Appendix Table A2).

Awareness of and consumption of lionfish

Most Belizeans and tourists have heard of lionfish, but few have ever tried eating it. However, most Belizeans and tourists would be willing to try a free sample, with significantly more tourists willing to try it. A summary of awareness and consumption of lionfish is shown in Table 2.1. Tourists were asked where, geographically, they first heard about lionfish (Appendix Figure A2). The majority of tourists (57%) first heard of lionfish in their home country. This question was not asked of Belizeans.

Perceptions of lionfish and neophobia

Belizeans who replied "no" to "If you were offered a free sample of lionfish at the market, would you be willing to try it?" were asked "Could you tell me why you wouldn't try lionfish?" Table 2.2 shows coded free responses. Several of these codes are similar. When we combined "Dangerous", "Scared",

"Neophobia", and "Misperception" into an overall "Misperception" category, these sum to 31 responses, or 36%.

Table 2.1 Belizeans' and tourists' responses to questions about awareness of lionfish and behaviors or intended behaviors around eating it.

*A * denotes a significant difference between Belizeans and tourists.*

Survey question	Belizeans	%	Tourists	%	Analysis
Have you ever heard of lionfish? "Yes" *	***n* = 400**	75.0	***n* = 399**	68.2	$\chi^2 = 4.589$, $df = 1$ $p = .032$, □ = -.076
Have you ever tried eating lionfish? (of those who have heard of lionfish and eat seafood) "Yes"	***n* = 282**	14.9	***n* = 273**	16.1	$\chi^2 = .159$, $df = 1$ $p = .690$
Have you eaten lionfish more than once? (of those who have tried it before) "Yes" *	***n* = 42**	81.0	***n* = 44**	54.5	$\chi^2 = 6.999$, $df = 1$ $p = .008$, □ = -.282
If you were offered a free sample of lionfish at the market, would you be willing to try it? (of those who eat seafood, have heard of lionfish, but have *not* tried lionfish before) *	***n* = 240**		***n* = 230**		$\chi^2 = 37.324$, $df = 2$ $p < .001$, $V = .277$
Yes		50.4		73.5	
No		35.8		12.6	
Undecided		13.8		13.9	

Table 2.2 Free response reasons Belizeans for why Belizeans would not be willing to try a sample of lionfish.

Belizeans only: Could you tell me why you would not try lionfish? (*n* excludes Belizeans who said they *would* try lionfish)	% ***n* = 86**
Dangerous	23.3
Preference	22.2
Lack information	18.6
Scared	8.1
Special preparation	5.8
Appearance	3.5
Health	3.5
Neophobia	3.5
Cautious of source	2.3
Cultural	2.3
Unsure	2.3
Misperception	1.2
Name	1.2
Not available	1.2
Trust	1.2

Food neophobia was measured using agreement scales of 1 (strongly disagree) to 5 (strongly agree) in a series of four questions shown in Figures 2.3 and 2.4. The statement in the negative was recoded and answers were summed to create a food neophobia scale ($\alpha = .698$), the highest possible score of which is 20. The mean rank for Belizeans was 285.44 and for tourists was 515.56. A Mann-Whitney U test found a significant difference in scores, meaning that tourists were more willing to try new foods (Mann-Whitney $U = 126025.5$, $p < .001$, $\eta^2 = 0.248$).

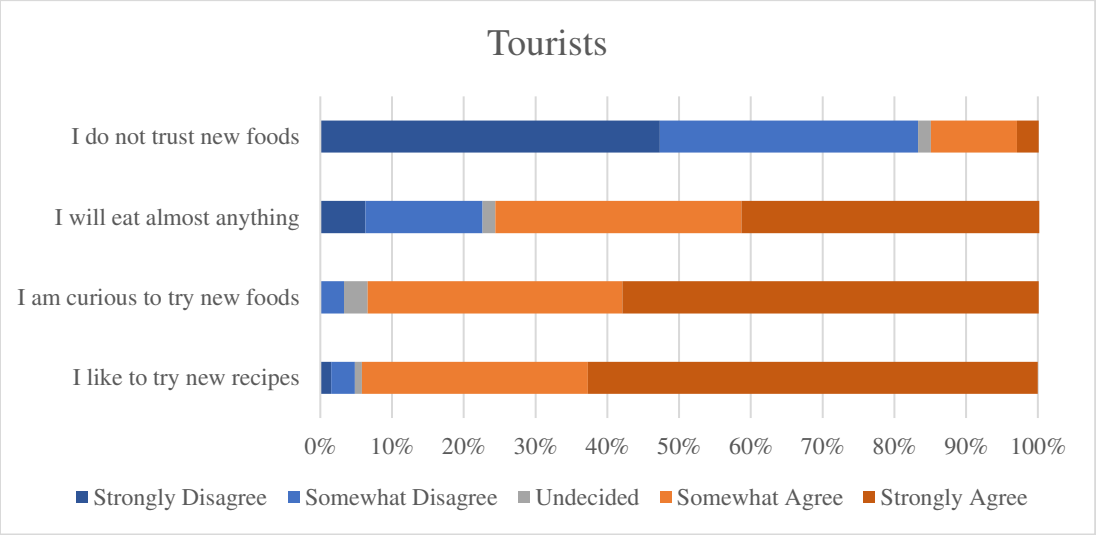


Figure 2.3 Stacked bar chart of responses to food neophobia statements among tourists (n = 400)

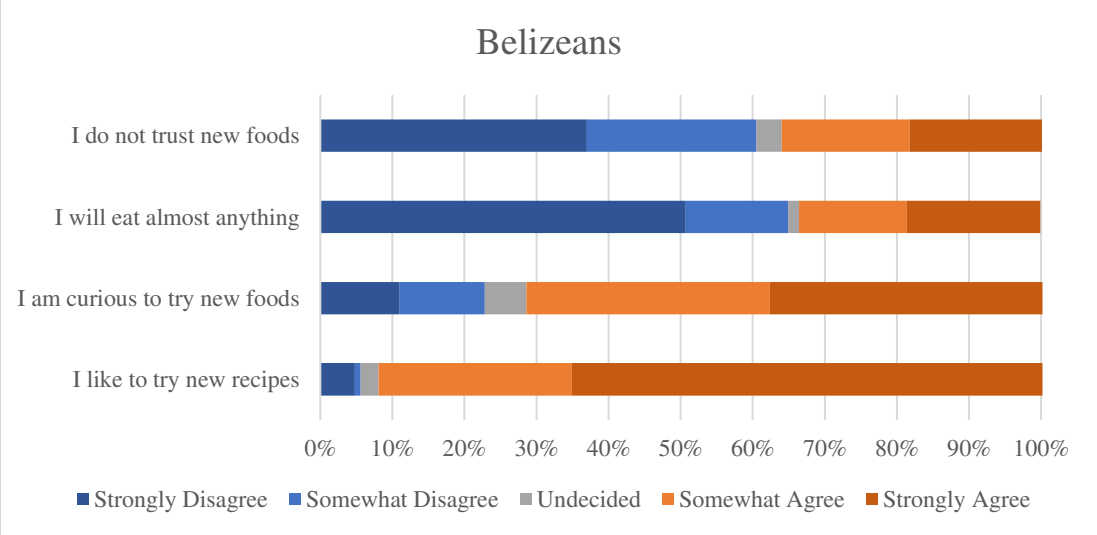


Figure 2.4 Stacked bar chart of responses to food neophobia statements among Belizeans (n = 400)

Knowledge

Knowledge about lionfish was assessed using a series of seven true or false questions about lionfish, shown in Table 2.3, with the total correct summed for a knowledge score. The highest score possible was 7. The median knowledge score of Belizeans was 5 (IQR = 3-5) and of tourists was 4 (IQR = 3-5). While there was no significant difference in overall lionfish knowledge scores between Belizeans and tourists, investigation into how each group answered individual questions, shown in Table 3, shows significant differences and important insights.

Table 2.3 Frequencies of true, false, and undecided responses to lionfish true or false questions and comparisons between Belizeans and tourists

*For analysis and scores, "Undecided" was counted as incorrect. Correct answers are indicated with a gray background. A * denotes a significant difference between Belizeans and tourists.*

Objective knowledge of lionfish was measured using the following true or false questions:	**Belizeans** ***n = 300***			**Tourists** ***n = 273***			**Analysis** $N = 573$, $df = 1$
	True	**False**	**Undecided**	**True**	**False**	**Undecided**	
1. Lionfish have always been in Belize's waters	34%	54%	12%	16%	60%	24%	$\chi^2 = 2.15$ $p = .143$
2. Lionfish are bad for the reefs	65%	20%	14%	62%	19%	19%	$\chi^2 = .726$ $p = .394$
3. Lionfish are moving to new areas	84%	3%	12%	78%	3%	18%	$\chi^2 = 3.35$ $p = .067$
4. Lionfish can't be handled*	35%	53%	12%	48%	36%	16%	$\chi^2 = 17.01$ $p < .001$, $\phi = .17$
5. People die from lionfish stings*	41%	28%	31%	32%	41%	28%	$\chi^2 = 10.22$ $p = .001$, $\phi = -.133$
6. Lionfish threaten Belize's fishing industry*	70%	14%	16%	59%	12%	29%	$\chi^2 = 7.60$ $p = .006$, $\phi = .12$
7. Lionfish meat is safe to eat*	53%	22%	25%	74%	8%	18%	$\chi^2 = 25.60$ $p < .001$, $\phi = -.21$
Average total score out of 7 (Mann-Whitney $U = 41948$, $p = .610$.)	Median = 5.0 IQR = 3.0 – 6.0			Median = 4.0 IQR = 3.0 – 5.0			

Belizeans and tourists had similar knowledge about the nature of the lionfish invasion, but Belizeans were significantly more likely to know that lionfish *can* be handled and that lionfish threaten

Belize's fishing industry. However, when related to safety, Belizeans' neophobic tendencies appeared. Tourists, as opposed to Belizeans, were significantly more likely to know that you *cannot* die from a lionfish sting and that lionfish meat *is* safe to eat. This last question is particularly important. A belief that lionfish is not safe to eat poses a major barrier to eating the fish at all.

Attitude

Attitudes toward purchasing lionfish were measured using a Likert scale with options of 1 (strongly disagree) to 5 (strongly agree) with a series of five statements, shown in Figures 2.5 and 2.6. For analysis, statements in the negative were recoded and answers to these five questions were summed to create attitude scales ($\alpha = 0.77$). The mean rank among Belizeans was 238.99 and among tourists was 339.75, (Mann-Whitney $U = 55353.5$, $p < .001$, $\eta^2 = 0.04$).

Additional attitude statements about lionfish and consumption were presented to Belizeans with options ranging from 1 (strongly disagree) to 5 (strongly agree) (Appendix Figure A3). Of the three hundred who responded to these questions, most agreed (14%) or strongly agreed (62%) that they would "pay more for a Belizean product than for a similar but less expensive one from somewhere else". In response to the statement "Lionfish is too expensive" 62% chose "undecided", and most disagreed (28%) or strongly disagreed (36%) with "Belizeans will never eat lionfish". Belizeans and tourists were presented with the statement "I am worried about lionfish" with the same agreement options from 1-5 (Appendix Figure A4). Most Belizeans strongly agreed (37%) or agreed (21%) with the statement "I am worried about lionfish". Among tourists, 15% strongly agreed and 34% agreed. Belizeans ($n = 300$, mean rank = 310.58) indicated significantly more agreement with this statement than tourists ($n = 273$, mean rank = 261.09) (Mann-Whitney $U = 33877.0$, $p < .001$, $\eta^2 = 0.02$).

Sex

Males and females were compared across all six measured variables (objective knowledge score, attitude score, neophobia score, heard of lionfish, tried lionfish before, willing to try a free sample) using

chi-square and Mann-Whitney U tests (Appendix Table A3). Females and Males did not significantly differ in responses to any variable among tourists, but among Belizeans, males had significantly higher knowledge scores, were more likely to have heard of lionfish, and were more likely to be willing to try a free sample.

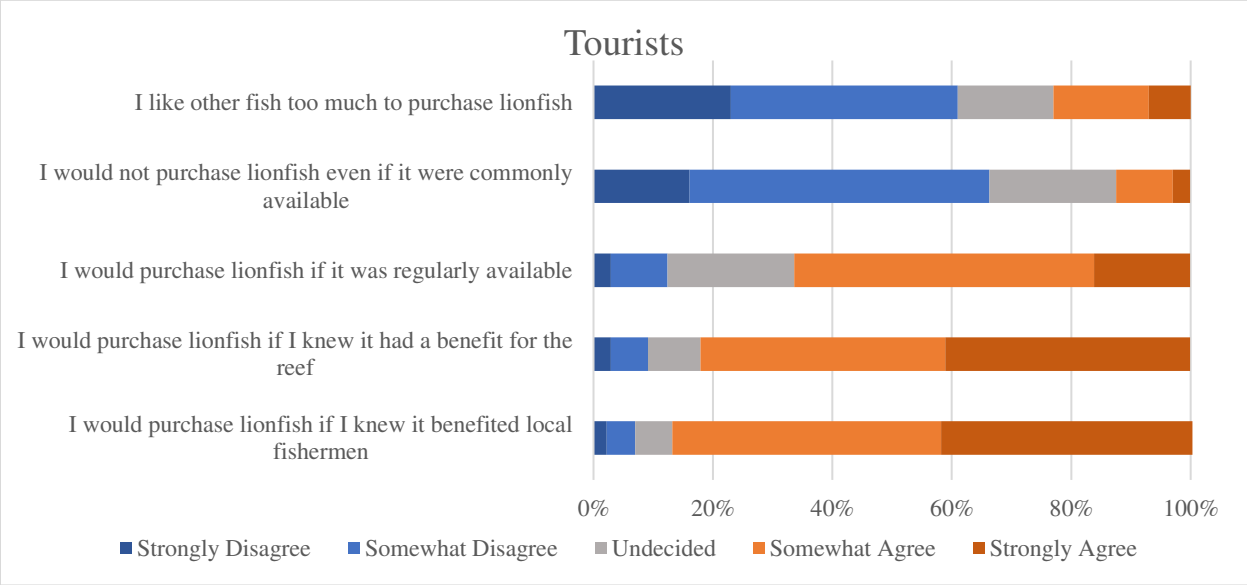


Figure 2.5 Stacked bar chart of responses to attitude statements among tourists (n = 300)

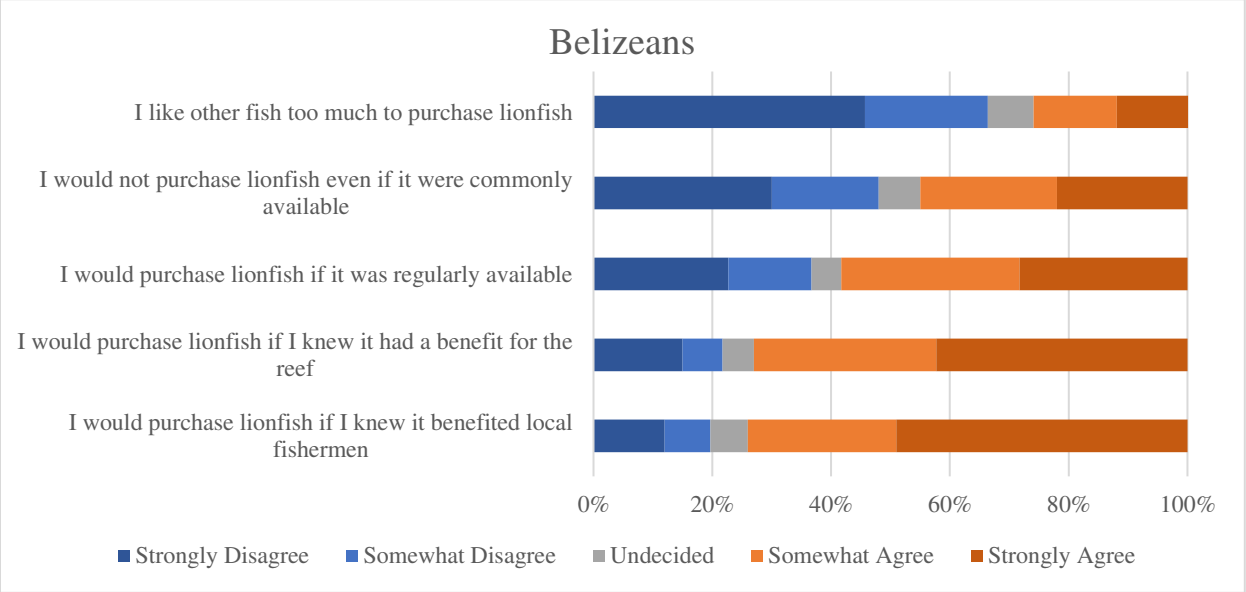


Figure 2.6 Stacked bar chart of responses to attitude statements among Belizeans (n = 300)

Predicting behavior

A binary logistic regression was used to test which of six characteristics – age, gender, sex, knowledge, attitude, or neophobia – best predicted a Belizean's and a tourist's willingness to try lionfish. In order to consider the role of moderators among Belizeans, the regression was run with various interaction effects, which were created using main effects product terms. Table 2.4 shows the main effects model as well as interaction effects model.

Across both main effects models, only attitude scores were significant predictors of Belizeans' and tourists' answer of "Yes" to trying a free sample of lionfish. When interaction effects were included, attitude had a moderating effect when combined with level of knowledge among Belizeans as well as a moderating effect when combined with neophobia among tourists. However, in both cases, the moderators had a negative effect on trial, suggesting a ceiling effect. Scatterplots of Belizeans' attitude and knowledge scores and tourists' attitude and neophobia scores are shown in Figure 2.7 and 2.8.

A binary logistic regression was run on responses to the seven true or false questions measuring knowledge of lionfish (Appendix Table A3) and found that, standing alone, one question was able to predict behavior for both Belizeans and tourists: "Lionfish meat is safe to eat" (T). Among Belizeans, those who were correct and answered "True" in comparison to all other respondents were 2.5 times more likely to say "Yes" to trying a free sample of lionfish (Cox-Snell $R^2 = .50$, $\beta = .92$, $df = 1$, $p = .001$, Exp(B) = 2.50, 1.47 – 4.26). Among tourists, those who were correct were 1.97 times more likely to say "Yes" (Cox-Snell $R^2 = .033$, $\beta = .68$, $df = 1$, $p = .022$, Exp(B) = 2.50, 1.10 – 3.52).

Discussion

Willingness to try lionfish

Overall, the findings illustrate that Belizeans are more aware, knowledgeable, and concerned about lionfish than they are interested in consuming it. That said, a majority of Belizeans agreed with attitude

Table 2.4 Binary logistic regressions analyzing knowledge, attitude, neophobia, gender, and age as predictors of being willing to try lionfish

The outcome variable was measured as "Yes" as opposed to all other respondents, including answers of "No", "Undecided" or missing. Standard errors are in parentheses. Confidence intervals of 95% are listed below the p-value for each odds ratio.

	Belizeans		**Tourists**	
Variable	**Main Effects Model n = 400**	**Interaction Effects Model n = 400**	**Main Effects Model n = 400**	**Interaction Effects Model n = 400**
Level of Knowledge Score	Exp(B) = .98 *p* = .804 .85 – 1.13 (.07)	Exp(B) = 1.80 *p* = .033 1.05 – 3.08 (.27)	Exp(B) = .93 *p* = .320 .82 – 1.07 (.07)	Exp(B) = .92 *p* = .26 .81 – 1.06 (.07)
Attitude Score	Exp(B) = 1.09 *p* = .001 1.04 – 1.15 (.03)	Exp(B) = 1.28 *p* = .001 1.10 – 1.48 (.07)	Exp(B) = 1.13 *p* = .001 1.05 – 1.22 (.04)	Exp(B) = 1.73 *p* = .012 1.13 – 2.65 (.22)
Neophobia Score	Exp(B) = 1.06 *p* = .093 .99 – 1.13 (.03)	Exp(B) = 1.06 *p* = .090 .99 – 1.13 (.04)	Exp(B) = 1.08 *p* = .075 .99 – 1.17 (.04)	Exp(B) = 1.72 *p* = .024 1.08 – 2.75 (.24)
Gender	Exp(B) = 1.58 *p* = .078 .95 – 2.63 (.26)	Exp(B) = 1.73 *p* = .039 1.03 – 2.90 (.27)	Exp(B) = .74 *p* = .253 .44 – 1.24 (.26)	Exp(B) = .72 *p* = .218 .43 – 1.21 (.27)
Age	Exp(B) = 1.02 *p* = .104 1.00 – 1.03 (.01)	Exp(B) = 1.02 *p* = .091 1.00 – 1.04 (.01)	Exp(B) = .99 *p* = .267 .97 – 1.01 (.01)	Exp(B) = .99 *p* = .277 .97 – 1.01 (.01)
Attitude * Level of Knowledge Score	------	Exp(B) = .96 *p* = .021 .93 – 1.00 (.02)	------	------
Attitude * Neophobia Score	------	------	------	Exp(B) = .98 *p* = .045 .95 – 1.00 (.01)
-2 Log Likelihood	377.37	371.68	346.24	341.77

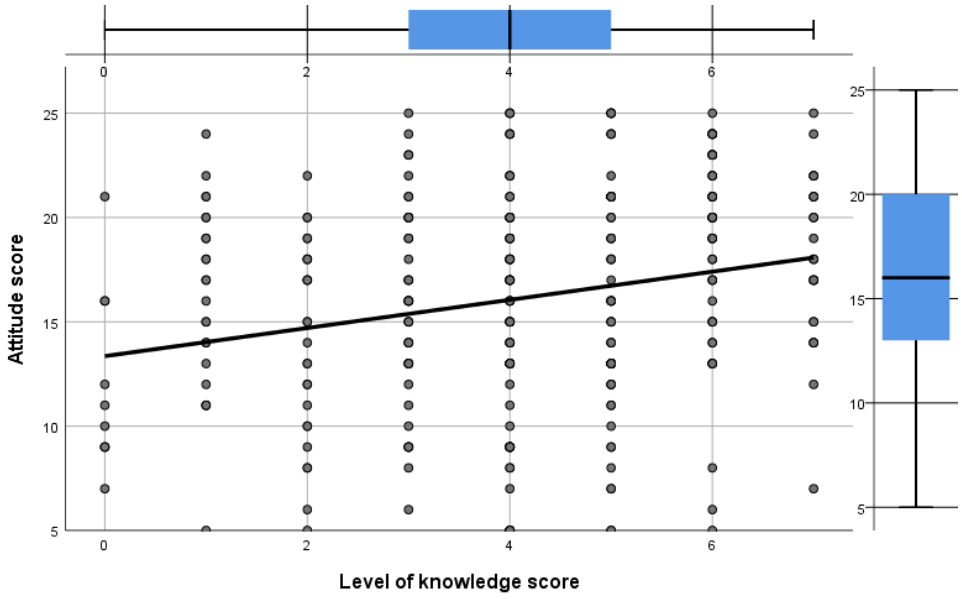


Figure 2.7 Scatterplot of Belizeans' attitude and knowledge scores with box plots

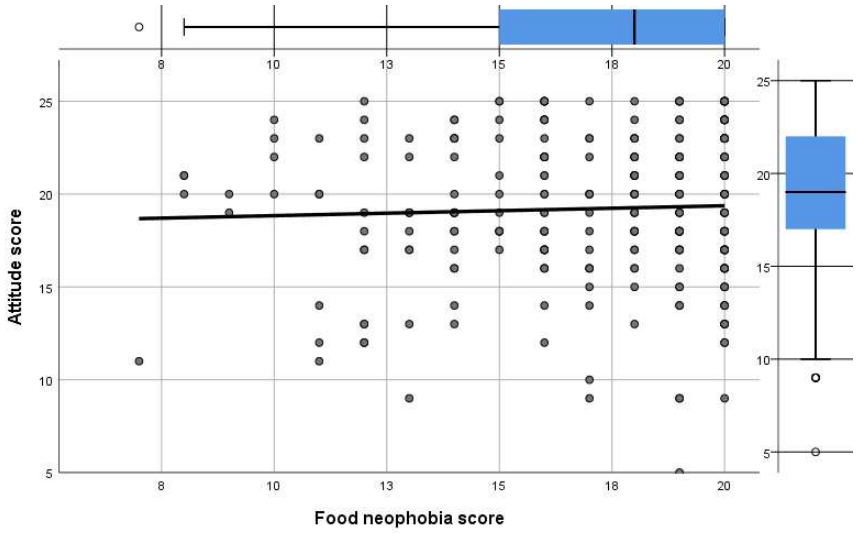


Figure 2.8 Scatterplot of tourists' attitude and neophobia scores with box plots

statements such as "I would purchase lionfish if I knew it would help local fishermen" and "if I knew it would benefit the reef". Scores from these attitude questions were able to significantly predict both Belizeans' and tourists' willingness to try lionfish. Belizeans also said they were willing to pay more for a product from Belize than for a less expensive version from somewhere else. So why do some Belizeans say they are concerned about lionfish and supportive of purchasing lionfish, but still unwilling to try it? While findings from the study concerning cultural seafood preferences may help explain some of this

contradiction (most Belizeans prefer to eat snapper than other fish), our regression analysis of true or false questions showed that the common misperception that lionfish is unsafe to eat significantly decreases Belizeans' willingness to try lionfish. Belizeans had more of a tendency (compared to tourists) to believe lionfish are unsafe to eat, which significantly decreased their willingness to eat it. This was true for tourists as well, but to a lesser extent. Furthermore, the most common reason Belizeans provided for why they would not try lionfish was danger, with other reasons frequently alluding to safety of eating or handling the fish, such as "Special preparation", "Scared", and "Health".

A closer look at neophobia and cultural norms

Based on sum knowledge scores and attitude questions, Belizeans and tourists were equally knowledgeable, but Belizeans were more concerned about lionfish. However, Belizeans were significantly less likely to be willing to try lionfish. In other words, while Belizeans appear interested in *solving* the lionfish problem, that does not always mean they are interested in *eating* lionfish. This may be partly explained by cultural norms. For one, snapper is by far the most popular fish in Belize: 67% of Belizean respondents named snapper as their favorite fish, with the next most popular fish chosen by only 4% of respondents. In addition, Belizeans are much more likely than tourists to say they like other fish too much to purchase lionfish. Although researchers have found taste to be an important component of food preference, it is important to note the role of culture and experience embodied in taste. The author of the book Home Cooking in the Global Village about Belizean cuisine and culture explains, "Taste is Visceral, embedded in bodily experiences from childhood. While people have some control over it and can cultivate new tastes, they are more often subject to being ruled by their preferences and pleasures." (Page 43). Research from the 1980s found that it can be difficult to break into the local seafood market because Belizeans "like West Indians, are highly selective in the kinds of fish they prefer" (Adams, 1985). Similarly, Pott (2010) concluded that snapper has long been a staple especially for low-income households.

These cultural preferences for specific fish create a barrier to introducing a new fish to Belizeans' diet. However, despite a large percentage of Belizeans responding that they like other fish too much to buy lionfish, the majority disagreed with the statement "Belizeans will never eat lionfish". One hypothesis might be that lionfish is too expensive for people to be willing to buy it, but most Belizeans and tourists replied "Undecided" to the statement "Lionfish is too expensive". This suggests that many respondents did not know how much lionfish cost. In addition, it may be possible that cultural variation in Belize provides a basis to experiment with new foods. Food traditions from each distinct culture are important to cultural and national identity (Spang, 2014). Belizeans tend to adopt and combine food traditions to create cross-cultural dishes (Spang, 2014). Thinking about lionfish as just another tasty fish or ingredient may help counteract the preference for snapper over lionfish.

It seems that Belizeans are open to new foods, but to a limit – and perhaps that limit is safety. When asked why they would not try lionfish, the most common answers were related to danger. The belief that lionfish is unsafe to eat will likely outweigh attitudes in favor of purchasing it. Before Belizeans are open to adopting lionfish as a new seafood ingredient, they must first know that lionfish is safe to eat despite their venom.

Who had a taste for lionfish?

Our research indicates it may be easier to sell lionfish to foreign tourists than Belizeans. In addition to frequent seafood consumption while visiting Belize, most tourists had already heard about lionfish before visiting Belize; and they scored higher than Belizeans in their attitudes about purchasing lionfish, their willingness to try new things, and their willingness to try a free sample of lionfish. Interestingly, while Belizeans were slightly more *worried* about lionfish than tourists, tourists were more willing to consume it. Furthermore, there was no significant difference in awareness or knowledge of lionfish between Belizeans and tourists. Thus, the effort to sell lionfish to tourists may not require very much awareness- or knowledge-building. Most tourists who had heard of lionfish learned about them in their home country, with only a small percent learning about them in Belize. In addition, most tourists

visiting Belize said they came for ecotourism/adventure, and therefore may be more open to novel experiences of the culinary kind. Novelty-seeking in tourists has been found to correspond with their satisfaction with novel food (Ji, Wong, Eves & Scarles, 2016). Research from the Belize Tourism Board confirms that young, adventurous travelers to the country may be increasing due to the recent increase in low-cost air carriers flying to the country, potentially providing more opportunity to successfully market lionfish to visitors (2018).

In addition, recent research on funding marine conservation in Belize through tourism found that foreign tourists (almost all of whom had participated in a marine activity while visiting) were willing to pay higher exit fees if the money was dedicated to conservation (Casey & Schuhmann, 2019). Almost all tourists in our study planned to participate in a marine activity while in Belize and the vast majority identified as a diver or snorkeler. Tourists' attitude scores tended to support purchasing and consuming lionfish if they knew it was helpful. These findings suggest that tourists in Belize may be willing to pay more for a lionfish meal in comparison to other meals if they know that they are helping the reef. Importantly, while tourists in Belize may seem like the preferable target market, Belizeans are a critical consumer group because they are a stable, year-round demographic, while tourists are for the most part seasonal. Because tourism is a luxury good (Smeral, 2003) and can be unstable in the face of natural disasters, pandemics, and political, economic and other dynamics, it is important to not rely solely on foreign tourists as consumers. The negative impacts of COVID-19 on tourism markets around the world demonstrate the need to take care not to rely on tourism more than necessary.

Where are Belizeans and tourists on the diffusion of innovation curve?

Diffusion theory defines the first 2.5% of a population to adopt a new behavior as the innovators and the next 13.5% as the early adopters (Rogers, 2003). In addition, researchers assert that a "chasm" exists between early adopters and the early majority on the diffusion curve that is difficult to bridge (Marra, Pannell, & Ghadim, 2003; Moore, 2014). Some researchers suggest that one should market a new product to innovators, then use what is learned from this group to identify and target the early adopters,

and so on. Given that 14.9% of Belizeans and 16.1% of tourists had eaten lionfish before, those who had tried lionfish in both populations would be considered innovators/early adopters. Thus, neither population has crossed the chasm into the early majority group (Moore, 2014). Removing misperceptions about the risks of consuming lionfish would likely increase Belizeans' willingness to try it and purchase it. A second barrier identified by asking participants who had never tried lionfish why they had not was availability. Most Belizeans and tourists agreed that they would purchase lionfish if it were commonly available.

Implications for marketing lionfish to Belizean consumers

While our results show an overall high level of seafood consumption among both tourists and Belizeans in Belize, Belizeans are far more likely to cook fish at home. This means that there is more potential to sell a fish to Belizeans at the market rather than in a restaurant. It could be concluded, then, that marketing lionfish to Belizeans should be done primarily in fish markets.

Notably, the customer experience and transmission of information occurs differently in a restaurant versus a fish market; most communication in a Belizean fish market occurs orally and is transmitted by the fisher or a fishmonger, while in a restaurant information may be provided orally by a server or written on a menu. Additionally, because local residents may have relationships with restaurant workers, fishers, or fishmongers and trust their recommendations, it may be sensible to educate these key influencers about messaging strategies for promoting lionfish.

Each venue presents pros and cons to marketing seafood and educating consumers about lionfish. Many fish markets are open-air, in some cases temporary structures (Pott, 2010), and are often areas where people are passing through, thus not always conducive to fish advertisement. Restaurants provide a second avenue to promote lionfish through chefs, servers, and menus. Research shows that restaurants play a key role in promoting sustainable seafood adoption (De La Lama, De La Puente, & Valdés-Velásquez, 2020; ASHOKA, 2009). In the case of lionfish, restaurants may also play an important role in

proving to patrons that the fish can be handled and eaten safely. This idea is supported by a study exploring barriers and benefits to increasing lionfish consumption in Belize City restaurants, which found that participants (who included both foreign tourists and Belizeans) who had not consumed lionfish before cited not seeing it on a menu as the reason they had not tried it before (Neidhardt et al. in prep.). As opposed to a fish market, where signage is less likely to be present, menus may offer an effective, non-personal method to at least bring awareness to lionfish among restaurant patrons – especially that it is safe to eat.

More generally, our findings illuminate messaging strategies for marketing seafood. Belizeans were more than twice as likely than tourists to name "health' as the main reason they choose to eat seafood. This finding is supported by Neidhardt et al. (in prep), which found that Belizean patrons also selected seafood for its health benefits. Taste was the second-most frequently chosen reason for eating seafood among Belizeans. This implies that an effective marketing strategy among local consumers may be to focus messaging on health and taste attributes of lionfish.

Implications for tourist consumers

Most tourists said they had or planned to have seafood daily or every other day while visiting Belize. Given this frequent seafood consumption combined with our assumption that tourists eat primarily at restaurants, it is likely that marketing lionfish to tourists should be done in restaurants. As for seafood messaging strategies, taste was the most frequently chosen reason for eating seafood among tourists and eating seafood because it is "fresh or local" was the second most frequent but was not mentioned even once by Belizeans. Therefore, when targeting tourist consumers in Belize, it may be wise to market lionfish and other seafood in restaurants with a focus on fresh, local and taste attributes.

Limitations and recommendations

While our data collection, methods, and analysis were carefully designed and executed rigorously, our findings should be considered with the study's limitations in mind. Some questions that

would have been useful for interpreting findings were left unanswered. For instance, we attempted to measure how much participants would be willing to pay for a lionfish meal. However, there is no one meal or currency that is relevant to all participants. Similarly, we were unable to solidify a wealth index that was applicable to all participants. In addition, so few participants had tried lionfish before that asking whether they thought lionfish was too expensive prompted a majority of "Undecided" responses. Future research measuring these characteristics in concert with measures of attitude, neophobia, knowledge, and behavior would help better identify key target markets and viability of the market in terms of price and profit. In addition, we recommend that future research identify the sources of misperception in Belize around whether lionfish is safe to eat and how to correct this key barrier to the lionfish market in Belize.

Conclusion

Overall, these findings show that there are clear opportunities for the lionfish market to grow and for more targeted messaging to occur. Belize is in the early adopter stage of the diffusion curve for lionfish consumption and consistent lionfish consumption is hampered by access to lionfish, neophobia, and misperceptions around whether lionfish are safe to eat. For one, only 15% of Belizeans and 16% of tourists had tried lionfish, but 50% of Belizeans and 74% of tourists who eat seafood and have heard of lionfish would be willing to try it. In other words, there is an enormous opportunity to introduce more consumers to lionfish. Beyond just trying lionfish, attitude questions across the board showed promise for Belizeans', and especially tourists', willingness to *purchase* lionfish given that it would help the reef, help local fishermen, or it is more available. In sum, given access to lionfish in markets and restaurants with the support of effective marketing strategies, a lionfish market in Belize has opportunities for growth.

CHAPTER 3: INVASIVE LIONFISH REMOVALS IN FLORIDA VARY BY SPEARFISHERS' MOTIVATION AND SOCIAL CAPITAL

Chapter Summary

Spearfishing remains the primary control mechanism for managing invasive lionfish in the West Atlantic. Management efforts in Florida have focused on engaging spearfishers in lionfish removal through market-based incentives, tournaments, and decreased regulations on the harvest and sale of lionfish. Research is lacking on what motivates lionfish hunters to participate in these activities. We share findings from a mixed methods study comprising responses from 75 semi-structured interview participants and an online structured survey of 186 spearfishers who hunt lionfish in Florida. Findings show that profit-motivated lionfish hunters and those who sell lionfish kill significantly more lionfish than those primarily motivated by other reasons or who do not sell. In addition, lionfish hunters who have a contact who helps them sell their lionfish remove significantly more. However, motivations such as protecting Florida's reefs, consuming lionfish, and enjoying the activity of lionfish hunting itself are more prevalent than profit. In addition, responses to personal norm statements show most lionfish hunters feel a personal obligation to kill lionfish. Results show that social capital that helps hunters sell lionfish plays an important role in increasing lionfish removal and in facilitating supply of lionfish for consumption. Furthermore, lionfish hunters' motivations to protect Florida's reefs, and personal norms obliging them to kill lionfish should help alleviate concerns about a market approach perpetuating the invasion.

Introduction

Biological invasions are considered one of the major drivers of biodiversity loss across the globe and are detrimental to ecosystem services and human well-being (Mačić et al., 2018). Each invasion creates conservation and management challenges with unique cultural and contextual factors that influence how a given society perceives the species and the control efforts to suppress it (Simberloff et

al., 2013). Many invasive species are initially introduced to a new geographic location as a resource, such as a source of meat (Simberloff et al., 2013). In other cases, the introduction is unintended, but communication efforts frame the invader in a way to encourage its consumption, as in the case of edible invaders such as Asian Carp (*Hypophthalmichthys nobilis*), nutria (*Myocastor coypus*) and brown trout (*Salmo trutta*) (Nuñez et al., 2012). When participation in removal of an invasive species offers a benefit to humans, an opportunity arises for engaging pro-environmental behavior that is unique, in which more consumption of a species is encouraged. In some cases, this leads to recreational harvest or market-based approaches to incentivize invasive species control (Nuñez et al, 2012; Pasko & Goldberg, 2014), as has been applied for invasive lionfish control.

Invasive lionfish

The invasion of the Indo-Pacific lionfish (*Pterois volitans*) was identified as one of conservation's greatest contemporary challenges in 2009 (Sutherland et al. 2010) and has since increased in importance among conservation organizations (Sutherland et al. 2019). After their introduction in the Atlantic in 1985, lionfish rapidly grew in number in the Caribbean region and West Atlantic (Côté, Green, & Hixon, 2013) and have become prevalent in the Mediterranean Sea (Azzurro et al, 2017). Lionfish are excellent invaders; they become sexually mature within their first year of life, reproduce frequently, and consume the young of native fish, compromising coral reef health and fisheries (Côté et al., 2013; Morris, 2009; Zeller, Graham & Harper, 2011). They have the appetite to decrease native fish numbers by 95% in some invaded sites (Côté et al., 2013). However, consistent site-specific culling allows native species to rebound to sustainable levels (Barbour et al, 2011, Côté et al., 2013). The primary means of culling lionfish thus far is spearfishing (Ulman et al, 2022), making spear fishers who target lionfish (hereafter "lionfish hunters" or "hunters") integral to lionfish population control. Though spearfishing remains the dominant method of lionfish control in Florida, understanding around what motivates lionfish hunters to kill lionfish is still needed (Morris et al, 2012).

Incentivizing lionfish removal

To combat the spread of lionfish and its negative ecological impacts, there are efforts in Florida and across the Gulf of Mexico and Caribbean to develop and maintain a market for lionfish (Chapman et al. 2016; Peiffer et al. 2017). In Florida, the National Oceanic and Atmospheric Administration (NOAA), the Florida Fish and Wildlife Conservation Commission (FWC), and Reef Environmental Education Fund (REEF), have worked to decrease barriers to commercial licensing to sell the fish (Ulman et al, 2022). These and other organizations, counties, and individuals have organized incentive programs, tournaments, tastings, and outreach events to combat the invasion as well. A market for lionfish is important for management because while tournaments can be effective at certain sites by removing large quantities of fish at one time, in other sites, to suppress lionfish numbers enough to protect reefs and native species, consistent, intensive removal is required (Green, Underwood, & Akins, 2017).

A question that arises within invasive species management is whether incentivizing harvest of a destructive species is a wise management strategy. Consequences could include creating a market that encourages stakeholders to maintain the species, and if the species generates profit, people may try to prop up the market by expanding the range of the invasion (Nuñez et al, 2012; Pasko & Goldberg, 2014). For these fears to be warranted, the harvesters would have to be motivated primarily by financial incentives, a question addressed in the present study.

On the other hand, too much dependence on a market approach could be problematic if lionfish hunters do not behave in perfect economic terms (as the price increases, so should supply). Bioeconomic models of the lionfish market, such as those produced by Barbour et al (2017) and Harris et al (2020) need more information on how much price, or profit, and other social factors influence lionfish hunters' willingness or ability to harvest more lionfish.

Motivation and invasive species control behaviors

More than sixty behavioral theories have been identified by the social psychology and behavioral economics fields for understanding determinants of behavior (McLeod, et al. 2015). Myriad theories have been applied to understand engagement in invasive species control, including the Theory of Planned Behavior (Prinbeck, Lach and Chan's, 2011), civic attachment (Niemiec et al., 2017), and collective action (Graham et al., 2019). Choosing the most relevant behavioral drivers and barriers to investigate for invasive species management depends on the specific context (McLeod et al. 2015).

In the context of invasive lionfish management in Florida, a large community of recreational and commercial lionfish hunters is engaged in lionfish removal. The market-based approach that has been applied assumes that the opportunity to make money from selling lionfish will increase removal behaviors. Therefore, assessing whether lionfish hunters are motivated to make money and, if not, what other motivations drive their lionfish removal behaviors, is important for determining the efficacy of a lionfish market and what other engagement approaches may be needed.

Morris (2012) emphasizes the need to understand motivations of lionfish hunters to generate engagement, but research on lionfish hunters' motivations is lacking. Understanding behavioral motivations is needed across the conservation field; conservation efforts cannot be successful without changing human behavior and "motivation is the driving force behind behavior change" (Schultz, 2011, p. 1080). Generally, "motivation is the psychological processes that cause the arousal, direction, and persistence of behavior" (Mitchell, 1982, p. 81) and is typically classified as intrinsic or extrinsic. Intrinsically motivated activities are those done without any reward other than enjoyment of the activity itself or feelings that result from the activity (Deci, 1971) while extrinsically motivated activities are those that are done to gain some other outcome such as a reward, approval, or to avoid punishment (Deci & Ryan, 2002). A third category is prosocial motivation, in which a person is motivated to take action based on concern for others (Batson, 1987), and which is the basis of pro-environmental behavior (Sevillano, Aragone & Schultz, 2013). Various studies have explored the effects of introducing incentives, especially

monetary, to encourage behavior in individuals who were previously intrinsically or prosocially motivated. Findings show that introducing an external incentive when individuals were already intrinsically motivated can decrease their productivity and effort in the activity, a phenomenon called "motivation crowding out" (Promberger & Marteau, 2013). Understanding lionfish divers' motivations, therefore, is important in considering whether incentive-based strategies will increase or, in the case of motivation crowding out, decrease their lionfish removal activities.

Personal norms and invasive species control behaviors

Personal norms are included as a key determinant within various behavioral theories, including norm activation theory, theory of interpersonal behavior (Triandis, 1977), and value belief norm theory (Stern et al., 1999). "A personal norm is a feeling of strong moral obligation and is activated by the awareness of the consequences of actions on others and the acknowledgement of personal responsibility for them" (McLeod et al., 2015, p. 66). Personal norms are precursors to altruistic behaviors (Schwartz, 1977). This is an important factor to consider in the context of invasive species removal behaviors because there is typically a positive correlation between altruistic motives and pro-environmental behavior, whereas egoistic orientations typically oppose these behaviors (Stern & Dietz, 1994). However, an invasive species market, such as the lionfish market, and recreational benefits from invasive species harvest present an opportunity to engage both egoistic and altruistic motivations. In addition, previous research on invasive species prevention among water recreationists showed that boater-anglers were most knowledgeable and felt the most personal responsibility for invasive species control (Seekamp et al., 2015). Lionfish hunters may feel similarly; as fishers who are invested in the marine ecosystem where they recreate, they likely feel a personal responsibility for these resources and for invasive species control.

Social capital and behavior

Social capital has been identified as an important factor associated with successful collective action for invasive species management (Graham et al., 2019) and as a form of support for invasive

species control in several contexts. For example, Graham and Rogers (2017) found that community events organizing collective weed control were equally important for forming and maintaining social relationships. Social relationships can also be important for increasing invasive species control behaviors in communities by sharing information, providing support for each other, and applying peer pressure to neighbors (Graham,2013). Social capital in the form of social sanctions from neighbors and neighbor interaction was also found to encourage resident action to control invasive little fire ants (*Wasmannia auropunctata*) in a neighborhood in Hawaii (Niemiec et al. 2017).

Lionfish hunters require various resources to be successful, including not only the equipment, knowledge, and means to dive and kill fish, but also the license and contacts needed to sell the fish. Some of these resources are easier to access through social connections. According to Lin, Fu, and Hsung (2001), social capital is defined as "the resources embedded in a social structure that are accessed and/or mobilized in purposive actions" (p.29). It is not enough for individuals in a community to hold certain resources, but also for people to be connected in a way that facilitates access to these resources. The structure of a social network can influence with whom resources are shared (Bruhn, 2011). Research has found that local organizations or individuals can play a role as resource brokers and determine whether community members have access to important day-to-day resources such as childcare (Small, 2006). In addition, social network and social capital research has been used in the conservation field to understand governance structures (Bodin and Crona, 2009) and the spread of information and pro-environmental behaviors (Chen, Taylor and Wei, 2012; Cooper, Reed and Pejchar, 2018; Barnes et al., 2016)

Because lionfish removal behaviors are related to recreational and commercial fishing activities that require a large amount of knowledge, skill and equipment, social capital is likely important for providing resources such as information about where to find lionfish, connections for selling lionfish, or gear to enable the behavior itself.

Study focus

This mixed methods study explores motivations of divers who participate in lionfish removal in Florida and measures their level of impact on the lionfish population based on the number of lionfish they personally killed in one year. The study was designed to answer the following research questions:

- What types of motivation are lionfish hunters primarily driven by?
- How does the number of lionfish killed vary by lionfish hunters' primary motivation and whether they sell lionfish?
- To what extent do lionfish hunters hold personal norms obliging them to hunt lionfish?
- What types of social capital help lionfish hunters increase the number of lionfish they kill?

We report findings from semi-structured interviews and a structured online survey of lionfish hunters identifying what types of motivations (i.e. to protect the reef, to make money, etc.) and social capital (i.e. having a dive buddy or someone who helps with selling lionfish) influence how many lionfish a lionfish hunter kills. In addition, we share findings on how much lionfish hunters agree with personal norm statements about removing lionfish to protect the reef. These findings are essential for assessing whether a market-based approach to lionfish control in Florida is an appropriate strategy because they show how the market, by incentivizing lionfish removal among those who are motivated to make money, affects lionfish removal. At the same time, by measuring lionfish hunters' personal norms related to lionfish removal, we assess the risk that a market incentive will appeal to lionfish hunters' egoistic motives and compel them to perpetuate the lionfish invasion due to the monetary and consumptive benefits they enjoy by hunting lionfish (Nuñez et al, 2012; Pasko & Goldberg, 2014). Finally, understanding what types of social capital are most important for generating increased lionfish removal is also crucial for lionfish management activities because it identifies what types of support lionfish hunters need to be more successful.

Materials and Methods

Study design followed applied questions important for lionfish management in Florida. The first author collaborated with FWC to identify key research questions and insights into the Florida lionfish hunting community. These conversations guided the design of semi-structured interview questions, which were piloted with a knowledgeable and active lionfish hunter in Florida. Based on guidance from FWC and this key informant, a final interview guide was created and avenues for contacting lionfish hunters to interview were identified – namely by attending tournaments throughout Florida. Following completion of most of the field-based interviews, a structured online survey was disseminated as well.

Semi-structured Interviews

Seventy-seven lionfish hunters participated in semi-structured interviews between May of 2019 and September of 2021 and were recruited via snowball and convenience sampling. Seventy-three participants were recruited and interviewed at lionfish tournaments or lionfish tastings. Two participants were contacted by phone after referral from another interviewee and two were known acquaintances of the first author. Sixty-seven participants were interviewed in person, eight over the phone, and two using Facebook Messenger's video chat.

All interviews were audio recorded with consent from the participant(s). Because lionfish hunters almost always participated in tournaments on teams and most were recruited and interviewed immediately, in some cases, multiple divers were interviewed at one time, resulting in a total of 47 recordings. Interview length ranged from 20 minutes to 1.5 hours. All interviews were facilitated by Author 1 except for one, which was facilitated by a research assistant, JAO. As this phase of the research was exploratory, with little known about lionfish hunters, their backgrounds, and reasons for engaging in removal, most questions remained broad. For example, several interview questions asked about the diver's experience (When did you start diving? What got you into spearing lionfish/why did you start? How deep do you typically go?). To inform applied research questions around lionfish hunters' motivations and their engagement with the lionfish market, other questions included "Why do you harvest

lionfish/what is your motivation for harvesting lionfish? Why do you think other people harvest lionfish? Have you ever sold lionfish?". To preliminarily assess the existence of lionfish hunters' social networks and inform the future online survey's questions about social ties, several questions inquired about lionfish hunters' relationships with others in the community. For example: "Where do you get information about lionfish from? Who else do you know who is involved in lionfish removal?". For the complete semi-structured interview guide see Appendix F.

The interviewer, author 1, held some emic perspective as a native Floridian from a family of recreational fishers, which helped position her with a more internal perspective and interact with participants more naturally. As a young outsider who was (at the time) not diving certified and not participating in tournaments, she posed no competition or threat to divers. This allowed them to feel comfortable sharing information about their strategies and dive sites that they may not share with other divers who compete for the same fish. After completing some fieldwork, the interviewer obtained diver certification and learned some of the skills and terminology that divers use to describe their experiences.

Online Structured Survey

To supplement interview data, an online structured survey was used to reach a larger sample of the Florida lionfish hunter population. Questions were developed to investigate relevant behavioral determinants for lionfish removal behavior based on preliminary interview findings and existing literature that links motivation, social capital and personal norms to pro-environmental behavior or invasive species control behavior. Framing of these questions was informed by already-conducted semi-structured interviews with lionfish hunters (three interviews were conducted after the launch of the online survey). Similar to Asah and Blahna's (2012) methodological approach to measuring motivation for environmental volunteerism, survey items about motivation were developed based on this specific context by using interviews with lionfish hunters to inform questions. Author 1 reviewed a subset of thirty interviews and answers to motivation questions to inform development of questions for the survey instrument. This allowed for specific wording of questions and response options that were most salient and understandable

to the sample population. A comprehensive list of multiple-choice options was generated based on themes from interviews for “Why do you choose to kill lionfish?”.

Social capital was measured using social network questions about relationships, or ties, with others in the lionfish removal community. This was done by first asking a domain-specific or contextual name generator question (McCarty et al., 2019), which prompts respondents to provide a list of alters based on a series of roles or types of relationships and then requests further details about interactions with these specific people. Respondents were asked to provide a list of up to ten people they know who fell into a series of ten domains, or categories, of relationships relevant to lionfish removal efforts. Similar to the survey items about motivation, the list of domains was developed based on types of relationships commonly noted by interviewees when asked open-ended questions about who else they know involved in lionfish removal. For each alter listed, respondents were then prompted to choose all that applied from a list of types of relationships.

The survey was piloted with ten people: five social science researchers who have studied lionfish management; two frequent lionfish tournament attendees, one of whom created jewelry from lionfish fins; and three lionfish hunters who varied in their skill and lionfish hunting effort. The survey was revised based on feedback and then revised again with the assistance of one of the lionfish hunters who had previously piloted the survey.

The survey was distributed primarily via email using Qualtrics software between June and October of 2021. Fourteen contacts whose referees only provided phone numbers were sent text messages with a link to the survey. In total, the survey was sent to 667 contacts who were involved in some way with invasive lionfish removal in Florida. FWC provided 590 contacts from a comprehensive list they had developed of people they knew involved lionfish removal efforts and had participated in the Lionfish Challenge (a multi-month competition to remove as many lionfish as possible in Florida). Twenty-five more contacts were included who had been interviewed by the first author but who were not on FWC’s list and 52 new contacts were sent the survey whose names and contact information were provided by

respondents in the name generator section of the survey. Of the 667 contacts, the response rate was 29% (n = 194) and the completion rate was 86% (n = 167). Incomplete responses that answered enough of the questions to inform research were included, for a total of 186 analyzed responses. Sample sizes for each frequency or test reported in this manuscript account for missing responses.

Thematic analysis

Transcriptions of interviews and development of a codebook were completed by author 1 and JAO to collaboratively determine the most salient themes and codes. Thematic analysis was applied to capture the breadth and depth of the content and have flexibility in connecting the various concepts and themes identified in the data (Braun & Clarke, 2006). Author 1 and JAO began thematic analysis by reading transcripts and writing memos. After becoming familiar with all interviews, Author 1 and JAO used an inductive approach by deriving codes from the data as they progressed through the interviews again. Through an iterative process of coding independently, then collaborating and editing codes, they produced an agreed-upon group of codes and meanings in the qualitative analysis software Dedoose. Author 1 then applied these codes to a subset of interviews, made final revisions to the codebook, at which point she used it to code all interviews.

Statistical analysis

Survey data were analyzed using Statistical Package for the Social Sciences (SPSS). Analyses of the relationship between type of motivation and the number of lionfish killed builds on previous research that applied motivational functionalism to identify how type of motivation predicts frequency of participation in environmental volunteering (Asah & Blahna, 2012). Similar to Asah and Blahna's (2012) use of frequency of volunteering as the outcome variable, our analysis focused on how many lionfish a lionfish hunter killed in one year. To increase reliability of this number, we requested respondents to consider a specific period of time with a time anchor (the beginning of the COVID-19 pandemic) that was universally identifiable: "For the year *before* the COVID-19 pandemic began (between March 1st 2019 and March 1st 2020), approximately how many lionfish <u>in total</u> did you personally kill in Florida? Note:

"Personally" means as an individual, so if you've collected lionfish on a team or in a group, please count only the ones you collected yourself. We understand it may be difficult to remember the exact number of fish so please simply provide your best estimate."

Statistical tests were used to measure what factors influence the number of lionfish a lionfish hunter killed in one year, which was not normally distributed. Nonparametric tests were used to compare different groups' impact: Mann-Whitney U tests were used to test for significant difference in number of lionfish killed based on top motivations. The same was done to measure how number of lionfish killed varied depending on a respondent's social capital, based on type of social tie. The Kruskal-Wallis test was used to detect whether a significant difference existed in mean lionfish killed among different types of top motivations, with subsequent Dunn's post-hoc pairwise comparisons to determine which specific paired motivations significantly differed. Because results from these tests showing money as a motivation and social capital that helps with selling lionfish Mann-Whitney U tests were used to test for significant difference in number of lionfish killed between those who sell versus don't sell lionfish. In addition to these analyses, we include reports of frequencies of agreement with personal norm statements about removing lionfish and other details that help contextualize our findings.

Results

Only respondents who indicated they had spearfished in the last two years were included in our analysis. Respondents were asked approximately how many lionfish they personally killed in Florida between March 1st 2019 and March 1st 2020 (hereafter "number of lionfish killed"). Collectively, respondents (n = 176) indicated they killed 46,743 lionfish that year, of which 42% were collected for a tournament or event and 31% were sold. There may be some overlap in lionfish sold and lionfish collected for a tournament given that many lionfish tournaments allow or encourage participants to sell their catch.

Motivations for hunting lionfish

Respondents were asked why they choose to hunt lionfish and then to rank the motivations they selected. Frequencies of motivations are shown in Table 3.1. The most common top-ranked motivation was "To help protect Florida's reefs" (91%), followed by "They taste good" (83%), "It's fun to hunt for them", and "To keep them from eating other fish that I like to hunt" (62%).

Table 3.1 Number and percent of respondents who chose each motivation in response to "Why do you choose to hunt lionfish?" and number and percent of respondents who ranked each as their top motivation.

Motivation	**Percent of respondents who chose motivation** *n* = 178	**Percent of respondents ranked as top motivation** *n* = 143
To help protect Florida's reefs	92.1%	53.8%
They taste good	83.7%	13.3%
It's fun to hunt for them	73.6%	16.1%
To keep them from eating other fish that I like to hunt	62.4%	6.3%
When other fish are out of season, I can still hunt for lionfish	42.1%	0.7%
To win prizes	39.3%	2.1%
It's easy to spear lionfish in comparison to other fish	38.8%	0.7%
It is more sustainable for fisheries to harvest lionfish than other fish	33.7%	2.1%
I like to compete with other lionfish hunters	32.0%	0.0%
Camaraderie with other lionfish hunters	25.8%	0.7%
To feel connected with my diving community	20.2%	0.0%
To make money from selling them	11.8%	3.5%
Research	1.1%	0.7%
FWC Challenge	0.6%	0.0%

Relatively few respondents indicated that "To make money from selling them" was the top reason they kill lionfish (n = 5, 4%), but this small group consisted of outliers who killed far more lionfish than anyone else, as shown inf Figure 3.1. A Mann-Whitney U test showed that this group removed more

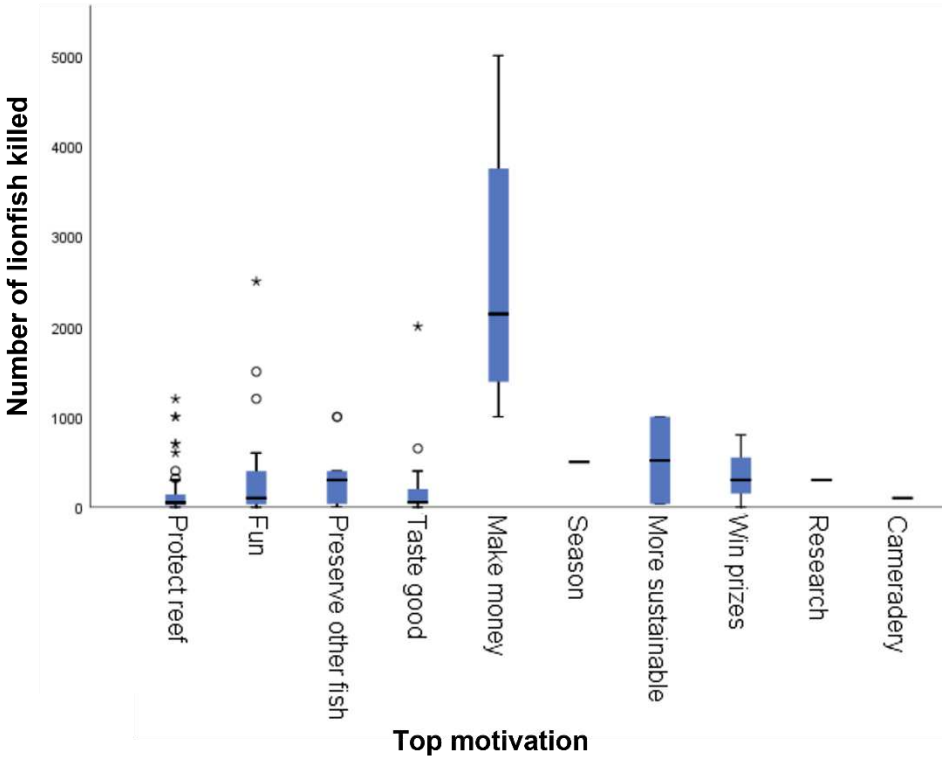


Figure 3.1 Box plots of number of lionfish killed for each top motivation

lionfish (mean rank = 134.00, n = 4; Note: one of the five whose top reason was making money did not indicate the number of lionfish they'd killed) than those who chose any other top motivation (n = 134, mean rank = 67.57, Mann-Whitney U = 10, p = .001, η^2 = .08). Four money-motivated individuals were responsible for 10,220, or 21% of the collective 47,733 lionfish killed by 176 respondents. To consider how each type of motivation, when chosen as the top motivation, compared to the rest, number of lionfish killed was compared for each motivation between those who chose it as a top motivation and those who did not. The complete list of Mann-Whitney U results is shown in Appendix Table D1.

Respondents were also asked what they typically do with lionfish after they've killed it and could choose multiple options. The most common response was "Take it home to eat" (n = 152, 82%), followed by "Share it with someone" (n = 65, 35%), "Turn it in for a tournament or competition" (n = 59, 32%),

and “Leave the lionfish in the water after I've killed it” (n = 29, 16%). The least common responses were “Sell it” (n = 17, 9%), “Donate it” (n = 16, 9%), and “Give it to someone to sell” (n = 11, 6%).

Interviews with lionfish hunters revealed similar findings to survey results. The most salient motivations identified in interviews were environmental stewardship, consumption, enjoyment/fun and money. A list of motivational themes from interviews is shown in Table 3.2. Most interviewees listed multiple reasons for hunting lionfish at once, sometimes explaining that it is because there are so many reasons to hunt lionfish that they do it.

I fish for lionfish because it's fun, for one. It fills my freezer so I never have to go to the grocery store. It tastes delicious. It helps the environment.. And there's so many side perks to it, why not? – 22

Table 3.2 Themes identified in analysis of interviews related to why lionfish hunters choose to hunt lionfish.

Motivation	**Description**	**# of excerpts**	**Exemplary quotes**
Environmental stewardship	Lionfish hunters hunt lionfish because they are concerned about the health of the marine ecosystem and know that removing lionfish helps protect the reef.	80	*To keep the reefs what they're supposed to be. Because they eat everything else. – 26*
Consumption	Lionfish hunters kill lionfish to eat them, because they taste good, or to share with friends or family for them to eat.	78	*Honestly, because they taste fantastic. They're the best fish you can ever eat – 11*
Enjoyment/Fun	Lionfish hunters kill lionfish for the sport and enjoyment of spearfishing in general or spearfishing lionfish specifically. They may say it’s fun or describe the game of finding lionfish as an enjoyable activity.	67	*I love the art of the competition. I love target practice in general… it almost just gives you like, a proverbial Easter Egg hunt. - 30* *I love hunting them. They're just fun, you know? – 51*
Money	Lionfish hunters kill lionfish to make money. They either generally see money as an incentive (without clarifying whether it is a profitable activity) or strive to make a profit from lionfish hunting and/or focusing on the commercial side of it. This could also pertain to monetary prizes from tournaments or other monetary incentives.	67	*My motivation is all money. I love diving, so it's just a way to make money while diving… - 43* *Everything we get, we generally eat. But, the lionfish, we've got a chance to actually make some money on as well. And it helps, you know, so we can have some free trips – 24*
Ease	Lionfish hunters feel the action of hunting lionfish (as opposed to diving/spearfishing in general) is relatively easy in that lionfish are actually very easy to shoot, especially compared to faster species like grouper and	25	*I mean and then there's the ease factor. It's pickin up apples underneath a tree. That is the sheer*

	snapper. The lionfish is sometimes seen as a good entry level spearfish and gets people interested in spearfishing other fish.		*difficulty level of what I'm doing. – 55*
Limitlessness	Lionfish hunters are inclined to hunt lionfish because there are no regulations limiting season, size or number of lionfish as well as easy and inexpensive access to the Saltwater Products License, needed to sell lionfish. Additionally, some divers see the lionfish population itself as limitless (although the abundance factor usually describes past population levels not current). Lack of regulation and abundance are often described together with the sentiment that in comparison to other fish you can catch as many as you want.	24	*There's a lot of 'em, there's no limits and rules, so you're not constantly wondering if it's too small to shoot a small fish. And then you can just leave it, like, spear and release, you know?* *– 66*
Subsidize hobby	Lionfish hunters sell lionfish not for actual profit but to help pay for the hobby; they might be able to pay for some of the gas, air tanks, or other costs.	20	*Trying to make a profitable hobby... It's not gonna be profitable. I wanna make it a less expensive hobby. – 64*
Preservation of other fisheries	Lionfish hunters enjoy spearfishing for other species and understand that lionfish threaten the viability of those stocks and this motivates them to kill lionfish.	12	*I want the baby fish to grow up, so kill those... By environmental, I mean let the sport fish grow so I can eat them. – 16*

Personal norms

A series of three 7-point Likert scale questions ("Strongly disagree" to "Strongly agree") measured lionfish hunters' personal norms related to killing lionfish based on their responses to the following statements: "I feel a personal obligation to help control the lionfish population in Florida", "When I see a lionfish but don't kill it, I feel regret", and "I feel it is my duty to hunt lionfish". Grouped together, this personal norm scale resulted in a Cronbach's Alpha of 0.89. The majority of respondents agreed or strongly agreed with these statements (Figure 3.2).

Selling lionfish

The majority of survey respondents indicated they do not sell lionfish (n = 144, 77%). Twenty respondents indicated they do sell lionfish (11%) and 13 indicated that they used to, but they don't anymore (7%). Of the twenty respondents who do sell lionfish, seven indicated their top motivation is to

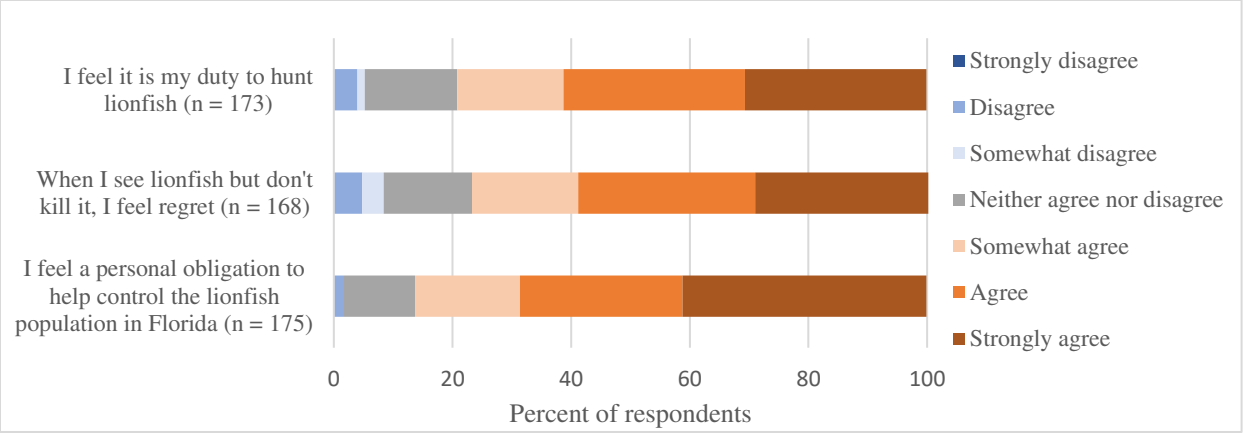


Figure 3.2 Percent of respondents who chose each of seven Likert scale options in response to statements about personal norms related to killing lionfish

protect Florida's reefs, five to make money from selling them, four because it's fun to hunt for them, two to keep them from eating other fish they like to hunt, and one for research (one did not answer this question). To consider how selling lionfish influences number of lionfish killed even when money is not the primary motivation, we removed the five money-motivated lionfish hunters and ran a Mann-Whitney U Test. Lionfish hunters who sell lionfish but whose top motivation was something other than to make money reported significantly higher numbers of lionfish killed (mean rank = 90.14) than those who do not sell (mean rank = 58.39) (Mann-Whitney $U = 1157.00$, $p = .002$, $\eta^2 = 0.08$).

Respondents who sell lionfish ($n = 20$) were asked why they choose to sell and could choose all that applied. The most common reason was "I like to sell lionfish so more people can try it [to eat]" (n = 16, 80%), followed by "I sell lionfish to help pay for my diving trips" (n = 15, 75%), "The lionfish market is an important strategy for controlling the invasion" (n = 11, 55%), "I value contributing to a sustainable seafood market" (n = 7, 35%), "It is meaningful for me to contribute to the excitement around lionfish" (n = 6, 30%), "Profits from selling lionfish is an important part of my income" (n = 4, 20%), and one person added an "other" reason, that it helps them pay for fun things and is a "side hustle". No one chose "Buyers ask me for lionfish".

Several interviewees who were motivated by money went to great lengths to catch large quantities of lionfish to make a profit or win money in a competition, sometimes risking physical harm to

themselves. One interviewee told of how he and his lionfish hunting partner pushed themselves to catch as many lionfish as possible and on one dive trip, this led to his partner getting "the bends", or decompression sickness, and having to quit diving permanently. Some tournaments have large monetary prizes as well, encouraging spearfishers to compete to catch the most lionfish.

I was hitting it hard, like 20 dives per week. That's not.. like what we do for these tournaments. No one NO ONE should do that. I want to think that we do it in the safest way possible. But I am carrying this lit bomb as safely as I can. It's still not. – 55

Another money-motivated lionfish hunter changed professions because it was no longer profitable enough given a perceived decline in the population.

So with the lionfish thing in the current state of affairs it's in it's like, well, it's hard to justify it, you know, because we all have mortgages and car payments and things like that. And that becomes the motivation, like, "okay, can we make money in this? No? Okay, then, let's not waste our time." – 43

One group of lionfish hunters who had previously attempted to sell lionfish for profit, commented

68: Who does it? It's a very select group. It's very small
[Interviewer confirms they are referring to people who are specifically commercial lionfish hunters]
68: That's a very small group
15: Very small – they're not in it for the profit
64: Ya you really have to sacrifice to go do that

Social capital for killing and selling lionfish

Respondents were asked to identify who they knew involved in lionfish removal, or their social network contacts, and what specific types of social ties they had with each person, including diving together, having a close relationship, helping each other when they began lionfish hunting, diving on each other's boats, sharing private numbers (GPS locations) with each other, and helping to sell lionfish.

Of those who responded to social network questions (n = 108), respondents who identified at least one person (n = 9) who helps them sell their lionfish reported a significantly higher number of lionfish killed (mean rank = 84.13) than those who did not have a social contact who helps them sell (n = 98, mean rank = 51.00) (Mann-Whitney U = 637.00, p = .003, η^2 = 0.081). This was the only singular

social tie that resulted in a significant difference in number of lionfish killed. See a full report of Mann-Whitney U tests on all social ties in Appendix Table D2. Although one can expect to detect significance in a certain number of relationships when a high number of significance tests are run, this result was clearly significant at $p = .003$. Notably, only one of the nine respondents who has a contact helping them sell lionfish ranked making money as their top motivation.

Themes related to social capital were identified in interviews as well. Many divers described close relationships with other lionfish divers, or social ties in which they introduced friends or family to lionfish hunting or vice versa. In Florida, the Saltwater Products License (SPL), an accessible and inexpensive commercial license, is required to sell lionfish. Some divers who have sold lionfish mentioned that they had a friend who had the necessary license to sell their lionfish for them. In some instances, groups of divers would pool their lionfish together and have one primary person with a SPL who sold it for them. For example, they may all go diving together on one boat and sell their combined catch under one license. This was more efficient than everyone selling their catch individually, especially when as individuals, they didn't catch a large quantity.

Every other person I know who did lionfish brought them to me. I didn't charge anyone anything. I wasn't like, you know, I wasn't charging to sell them to Whole Foods. People would bring fish to [me] so that when the [truck] came they can pick them up from one location. – 43

He's got a license, so we kind of all lump it. – 73

One of our guys has a SPL license… And so he sells for us to buyers and so forth. – 36

Discussion

Motivation and social capital matter

Findings show a combination of top motivations among lionfish hunters, including intrinsic (It's fun to hunt for them), extrinsic (They taste good, or consumption), and prosocial (To help protect Florida's reefs). Although few lionfish hunters listed their top motivation as money, these individuals killed significantly more lionfish than those primarily motivated by another reason, suggesting that more

prosocial motivations are not the more potent motivators for killing lionfish. Similarly, comparing individuals motivated by money versus to protect Florida's reefs showed hunters motivated by money killed significantly more lionfish.

Lionfish hunters who sell lionfish but didn't choose money as their top motivation kill more than those who don't sell. Additionally, lionfish hunters who have a social contact helping them sell their lionfish kill more lionfish. Contacts who help hunters sell their lionfish likely serve as "resource brokers", or contacts that connect people who otherwise would not be linked (Diani, 2013; Gould and Fernandez, 1989). In this case, contacts who help sell lionfish may connect hunters with buyers or serve as a point person with whom everyone pools their lionfish together to sell, as indicated in interviews.

Notably, the primary motivation of those who sell lionfish is most often not money. Furthermore, even when money-motivated individuals were removed from this subgroup, lionfish sellers killed significantly more lionfish than those who do not sell. Lionfish hunters who sell lionfish are choosing to sell lionfish even though the monetary benefit of doing so might not be their top reason for participating in control efforts. Responses to the question about why they choose to sell their lionfish show respondents do so for a number of reasons, including prosocial reasons such as that the lionfish market is an important strategy to control the invasion. This suggests that the market encourages lionfish removal even when money is not the primary goal. In some cases, it appears to be a secondary goal; the most common response for why hunters sell lionfish is to help pay for dive trips.

In both interviews and survey responses, lionfish hunters almost always indicated multiple motivations for hunting lionfish, including a mixture of egoistic, altruistic, and biospheric. Egoistic motives typically contradict altruistic and pro-environmental behaviors (Stern & Dietz, 1994). However, lionfish are a desirable food fish, can be sold for money to help finance spearfishing and diving activities that spearfishers already enjoy, and are fun to catch, all of which enact lionfish hunters' egoistic motivations. At the same time, killing lionfish enacts biospheric and altruistic motivations because it helps protect the native ecosystem. Even lionfish hunters who do not make money from their harvest

benefit from consumption, the second-most common motivation for hunting lionfish, and from enjoyment of the activity. Lionfish hunting is thus a rare pro-environmental behavior that satisfies the suite of human motivations – egoistic, altruistic, and biospheric (Stern et al., 1993) and stands in contrast to typical pro-environmental and invasive species control behaviors that rely on primarily altruistic or biospheric motivations. The importance of appealing to all three motivations reflects recommendations from literature on these types of values. Groot and Steg (200() advise that interventions to encourage pro-environmental behavior should reduce conflict between egoistic, altruistic, and biospheric values and that altruistic and biospheric values are insufficient for encouraging high-cost behaviors, which lionfish hunting is. Furthermore, Groot and Steg (2009) argue that altruistic and biospheric values should be emphasized more to ensure sustained involvement.

Sustaining motivation and the lionfish market

Relatively few respondents ranked money as their top motivation, which is an important limitation if a lionfish market is to be effective as those who were not primarily motivated by money accounted for 79% of the collective lionfish removed in one year by the study's respondents. Interview data explain why there may be a scarcity of money-motivated individuals and lionfish sellers in the study sample: removing enough lionfish to make a reliable income requires substantial effort, risk, and is more difficult when lionfish population densities decrease. The timing of these interviews (2019 – 2021) coincided with a recent decrease in densities. Harris et al (2020) found that an ulcerative skin disease caused changes in lionfish size resulting in recruitment failure in summer 2018 and a 75% decrease in population density on natural reefs. Decreases in lionfish density, whatever the cause, have been shown to impact the viability of lionfish markets and lionfish hunters' commercial success. Malpica-Cruz et al (2021) found that lionfish hunters in Cozumel, Mexico were effective at removing large numbers of lionfish, thus decreasing their density on native reefs. However, this success also resulted in decreased landings, causing diminished market interest and the overall demise of the lionfish market in the area. Our interview data points to this possibility in Florida. Further research on what barriers lionfish hunters face

in Florida in terms of the quantity of lionfish they kill and sell are needed to determine the stability of the lionfish market given fluctuations in population density.

Malpica-Cruz et al (2021) underscore the importance of a consistent supply of lionfish to maintain interest in the lionfish market. If spearfishers remain the primary means of lionfish control and if the lionfish market in Florida is to be a viable control strategy, management efforts may need to engage a mixture of motivations so that lionfish continue to be removed. Ezzine-de-Blas (2021) argues that activating intrinsic motivations of conservation incentive program beneficiaries generate more ownership and lasting behaviors beyond the timeframes of financial incentives. Because prosocial motivations for killing lionfish, such as protecting Florida's reefs, are not based on financial incentives, they may be longer-lasting and more sustainable from a management perspective. Furthermore, most respondents who sell lionfish indicated they do so for prosocial reasons, such as that they like to sell lionfish so more people can try it, they think the lionfish market is an important strategy for controlling the invasion, and they value contributing to a sustainable seafood market. For management efforts to effectively support a lionfish market, it may be necessary to encourage hunters to sell lionfish for prosocial reasons, such as that maintaining consistent supply of lionfish to buyers is important for lionfish control.

Prosocial motivations

Understanding motivations of lionfish hunters is important for addressing concerns that hunters may attempt to perpetuate the invasion in response to financial incentives associated with a lionfish market (Pasko, S. & Goldberg, J., 2014; Nuñez et al, 2012). Most respondents indicated that helping to protect Florida's reefs was one of their motivations for killing lionfish, which suggests it is unlikely these individuals will attempt to perpetuate the lionfish invasion. In fact, most respondents ranked "to help protect Florida's reefs" as their top motivation. Personal norms are important factors that motivate people to behave altruistically (Harland, Staats & Wilke, 1999) and have been found to play a key role in motivating pro-environmental behaviors (Ates, 2020) and invasive species control for other aquatic invasions (Seekamp et al., 2015). Most respondents agreed with statements about feeling a personal duty

to kill lionfish and many strongly agreed. Lionfish hunters' personal norms and prosocial motivations extend their purpose beyond extrinsic rewards and appear to be in line with lionfish control goals.

Recreationists and invasive species control

Invasive species control behaviors are often situated in contexts where the task of removing the invasive is a chore or financial burden, such as in the case of weeds (Graham & Rogers, 2017) Western Corn Rootworm (Kropf et al., 2020) and various aquatic invasives (Seekamp et al., 2016). In contrast, spearfishers in Florida enjoy hunting lionfish. In the case of recreationists, such as boater-anglers, feelings of personal obligation to help protect the ecosystem where they recreate motivate them to participate in invasive species control (Seekamp et al., 2016). Lionfish hunters, also motivated by personal obligation, are asked to not only help protect the ecosystem where they fish or recreate, but also to do so by participating in the very activity they enjoy doing anyway: spearfishing. The suite of motivations lionfish hunters identified represents a general mental model that there's simply no downside to lionfish removal; they are encouraged to do more of what they enjoy or make money from and at the same time can feel good about contributing to the local environment in a positive way as opposed to putting pressure on other fish populations they care about sustaining. This points to an important opportunity for invasive species control where recreationists can be engaged in a similar way. In addition, it begs the question of what creative ways we might engage people in other pro-environmental behaviors by appealing to egoistic orientations, such as enjoyment of an activity *in addition* to altruistic or prosocial motivations rather than categorizing these motivations as mutually exclusive.

Motivation crowding out

Behavioral economists have found that external or financial incentives can sometimes crowd out other motivations and decrease desired behaviors (Frey & Jegen, 2001; Gneezy et al., 2011), but this phenomenon varies in the context of pro-environmental behaviors and motivations (Ling and Xu, 2021, Rommel et al., 2015). In the case of lionfish hunting, our findings suggest that financial incentives significantly increase removal of lionfish among the few who are primarily money-motivated. Most other

lionfish hunters are not money-motivated, but also do not sell lionfish, suggesting that among these individuals, a crowding out affect caused by the lionfish market is unlikely because lionfish hunters do not necessarily sell their fish to begin with. However, longitudinal research is needed to determine changes in lionfish hunting motivation and behavior after introduction of financial incentives. Nonetheless, combining management strategies in a way that engages lionfish hunters' various motivations, as tournaments likely do, will help reinforce existing motivations, such as consuming the fish and protecting the reef, and ensure continual removal of lionfish in the long-term.

Implications for lionfish management

Because lionfish hunters who are money-motivated or sell lionfish are more impactful than others, supporting a market for lionfish is important for lionfish control. Our finding that lionfish hunters kill more lionfish if they have a social contact who helps them sell suggests that supporting the process of selling lionfish, such as by allowing lionfish hunters to combine their harvests into one point of sale for pick up or delivery to a wholesaler, would increase lionfish removal. Currently, lionfish hunters are relying on each other to help streamline this process. At the same time, the proportion of lionfish hunters who are money-motivated is very small, and the incentive to invest the time and resources necessary to remove large quantities of lionfish only persists so long as lionfish densities are high and ensure large enough harvests to make a profit. Learning from the demise of the lionfish market in Cozumel caused by decreased lionfish densities (Malpica-Cruz, 2021), for a lionfish market to be viable in Florida, more lionfish hunters, including those who are not money-motivated, will need to sell lionfish so that wholesalers and restaurants have a consistent supply. This enables wholesalers and restaurants to market the fish and ensure consistent demand and worthy pricing, something confirmed in a study on restaurants in Florida that sell lionfish (Burgess et al, *in review*). Most respondents who sell lionfish indicated they do so for prosocial reasons, such as because the lionfish market is an important control strategy. Therefore, engaging lionfish hunters in selling lionfish by communicating that it is important for lionfish control (not just to make money) may help sustain the market and increase lionfish removal collectively. In addition,

because money-motivated lionfish hunters may not be long-term or consistent participants in lionfish removal efforts due to fluctuating densities, it is important for management to engage other lionfish hunters and their various motivations, including protecting the reef, eating lionfish because it tastes good, it's fun, and it helps preserve other fish species spearfishers like to target. This will help ensure persistent culling in the long-term despite changes to lionfish densities and potential decreases in the amount one profit-driven lionfish hunter is able to harvest.

Conclusion

Lionfish control efforts are reliant on lionfish hunters throughout the invaded range. Thus, understanding the motivations and perspectives of lionfish hunters is essential to effective management, including engagement and collaboration. Our findings reveal that money-motivated lionfish hunters kill far more lionfish, but that many lionfish hunters choose to hunt and sell lionfish for a variety of reasons, usually a mixture of intrinsic, prosocial and extrinsic motivations. Furthermore, among those who sell lionfish, more are motivated to make money to help pay for their dive trips than to make a profit and most were also driven by prosocial motivations to sell lionfish such as so other people can try eating it. In addition to motivation, our findings show that social capital plays a role in whether lionfish hunters sell lionfish as well as their impact – having someone to help sell their fish is associated with more lionfish killed. Thus, it is important for management efforts to not only focus on maintaining a market for lionfish, but also on continuing to cultivate a lionfish hunting community.

CHAPTER 4: DOES PROVIDING AN EXAMPLE OF A SOCIAL NETWORK MAP INCREASE RESPONSES TO SOCIAL NETWORK QUESTIONS IN AN ONLINE SURVEY?

Chapter Summary

Social network research often depends on the willingness of survey respondents to provide personal information about themselves and their alters. Strategies for survey design that increase willingness to share this information are necessary for social network research to be feasible across disciplines. We conducted an experiment in which half of our respondents (n = 350) received an online survey that included an example network map and the other half (n = 350) received a survey that did not, with the hypothesis that the map which visualized what could be done with the data provided by respondents would increase respondents' willingness to share their own social network data. We found that the map did not increase provision of network contacts and did not influence the types of ties reported.

Introduction

The social network approach

The social network approach allows scientists to study ecological and social phenomena at a more holistic level than the individual (Borgatti & Molina, 2003; Freeman, 2004). Findings from social network studies have revealed that social environments can have more influence on behavior than personality, attitudes, and other individual-level factors (Latkin & Knowlton, 2015). Social network research is applicable across many disciplines and is increasingly used to help find solutions to a variety of societal problems. Research on social networks present myriad ways in which networks determine resilience in the face of challenges; success of social movements; access to resources such as employment, childcare, and education; and the spread of behavior (Giuffre, 2013; Rainie & Wellman, 2012).

Social network data collection: challenges and strategies

When researchers cannot collect data on individuals' relationships from existing sources such as archives or social media, they ask individuals about their own networks. This type of SNA research depends on the willingness of respondents to share personal information about themselves and members of their network. In research on hard-to-reach populations, such as drug users, reliance on people to provide this information is heightened because the most effective way to identify network members is through snowball sampling (using respondents to identify other network members) (De Brún & McAuliffe, 2018). The intrusiveness of SN questions can create a barrier to soliciting reliable SN data, and can be even more difficult depending on the platform, such as in-person versus online surveys (Borgatti et al., 2013; Borgatti & Molina, 2003). This barrier is heightened when survey questions prompt respondents to reveal sensitive information or details about illegal or forbidden activities such as sharing security information (Dang-Pham et al., 2017) or sharing contact tracing information during the COVID-19 pandemic (Cho et al., 2020). In addition, SN maps can inadvertently reveal an individual's identity in smaller networks based on contextual clues and labelling of node attributes, even when presenting aggregate results and removing personally identifying information (Task & Clifton, 2014; Yuan et al. 2013).

In organizational contexts, these barriers can be overcome through strategies such as expressing the importance of the SN information, clarifying exactly how the information will be used, and building rapport with leadership (Borgatti & Molina, 2003; Agneessens & Labianca, 2022). However, in many settings, this level of interaction with respondents is not possible. Instead, surveys and questionnaires are the primary means of SN data collection (O'Malley & Marsden, 2008) and for SNA, high response rates are more important than other forms of survey research to accurately depict the network. This is especially important for whole networks, which capture connections among every individual in a network, as opposed to an ego network, which maps the network of each individual respondent. SNA and visualization rely on collated information from individuals to measure a whole network; thus, every

nonresponse creates a gap in the data and can impact how results are interpreted (De Brún & McAuliffe, 2018). A 75% response rate of the network is typically recommended for reliable analysis of SN data. Certain SN measures such as centrality and betweenness are sensitive to response rates that fall below 80% and 70% of the network (De Brún & McAuliffe, 2018). Therefore, strategies to increase respondents' willingness to provide network information when participating in SN surveys can help increase success and opportunities to conduct this type of research.

This study sought to test a strategy to increase respondents' willingness to provide network data by including an example SN map in the introduction of an online survey that showed respondents a possible visualization of aggregated responses. The intention was to generate interest and support for the research, thereby motivating responses to SN questions. This is the first study to test the efficacy of including an image of a network map to increase respondents' willingness to answer SN questions.

Exploration of similar methods has shown that visualizations can influence responses and respondents' experiences. Studies using online surveys that engage respondents through an interactive platform in which they draw their own network map found this format is appealing to and easily understood by a broad range of participants (Tubaro et al., 2013; Tubaro et al., 2015). Images illustrating specific questions have been found to influence respondents' choices based on the content of the picture. For example, in one study, respondents who saw a picture of a healthy woman as opposed to a sick woman rated their own wellbeing as less healthy (Couper et al., 2007). In another study, header images and location of those images in an online survey influenced students' responses about their stress and leisure time (Trübner, 2020). In another study, surveys about various topics found that the content of images influenced respondents' answers, such as respondents indicating higher frequencies of a behavior when shown a picture depicting a high frequency of the behavior (Couper et al. 2004). However, there is no existing research on how providing an example SN visualization in an online survey influences the quantity or types of responses to SN questions.

The purpose of this experimental study was two-fold: (1) To test the hypothesis that providing an example SN map in the introduction of the survey would increase respondents' provision of SN information and (2) To determine if and how providing an example SN map changes the types of contacts respondents provide in the name generation step of the survey. Other research questions addressed in the analysis phase included the how respondents' gender, time spent on the introduction page where the visualization was placed, and sensitivity of the information requested influenced their provision of SN information. Findings provide insights into the influence of a SN visualization on responses and on types of reported ties, all of which are helpful for researchers who are using online surveys to collect SN data.

Methodology

Survey and experimental design

The portion of the survey which included an example SN map is shown in Figure 4.1. The topic of the survey instrument with which this methods experiment was conducted was the pro-environmental behavior of removing an invasive marine species in Florida called lionfish (*Pterois* spp.), an activity primarily accomplished by recreational and commercial spearfishers and divers, who are often referred to as lionfish hunters. The structured survey instrument was originally designed for a larger study on lionfish hunters in Florida assessing the behaviors, motivations, and social networks of divers who remove lionfish from Florida waters. For this paper, we will describe only aspects of the survey design that are relevant to this methods experiment.

To test the hypothesis that providing respondents an example of a SN map would increase responses to questions that solicited SN information, half of our contacts received a survey with an example fictional SN map showing the type of findings and visualization their responses to these questions could help produce. The full survey instrument is provided in Appendix E. To incentivize completion of the survey, respondents were invited to enter a raffle. The following was included in the introduction text of the survey: "To thank you for your time, your name will be entered into a raffle

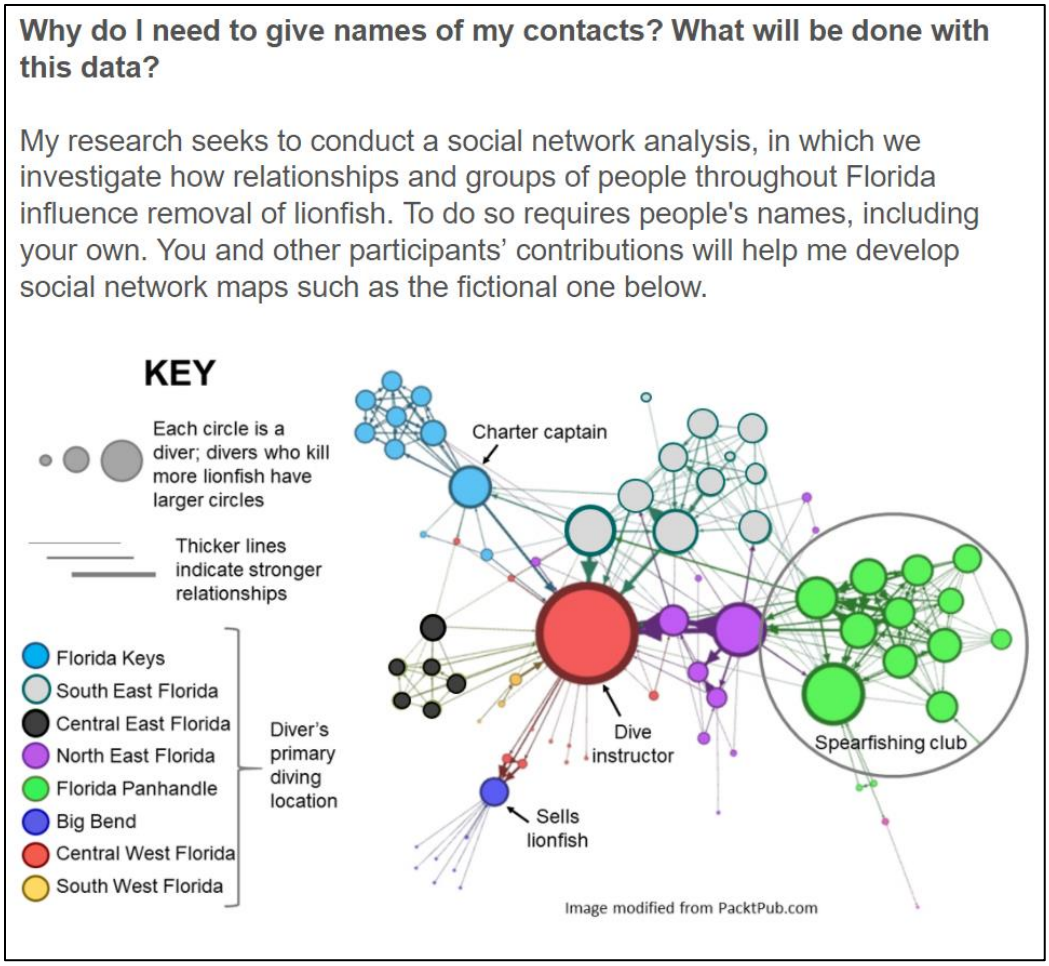


Figure 4.1 Instrument with an example SN map included in the consent page

drawing provided by the Fish and Wildlife Foundation of Florida. Multiple prizes are available, including an Engel Backpack Cooler, Engel Silipints, and Reef Rangers nalgenes."

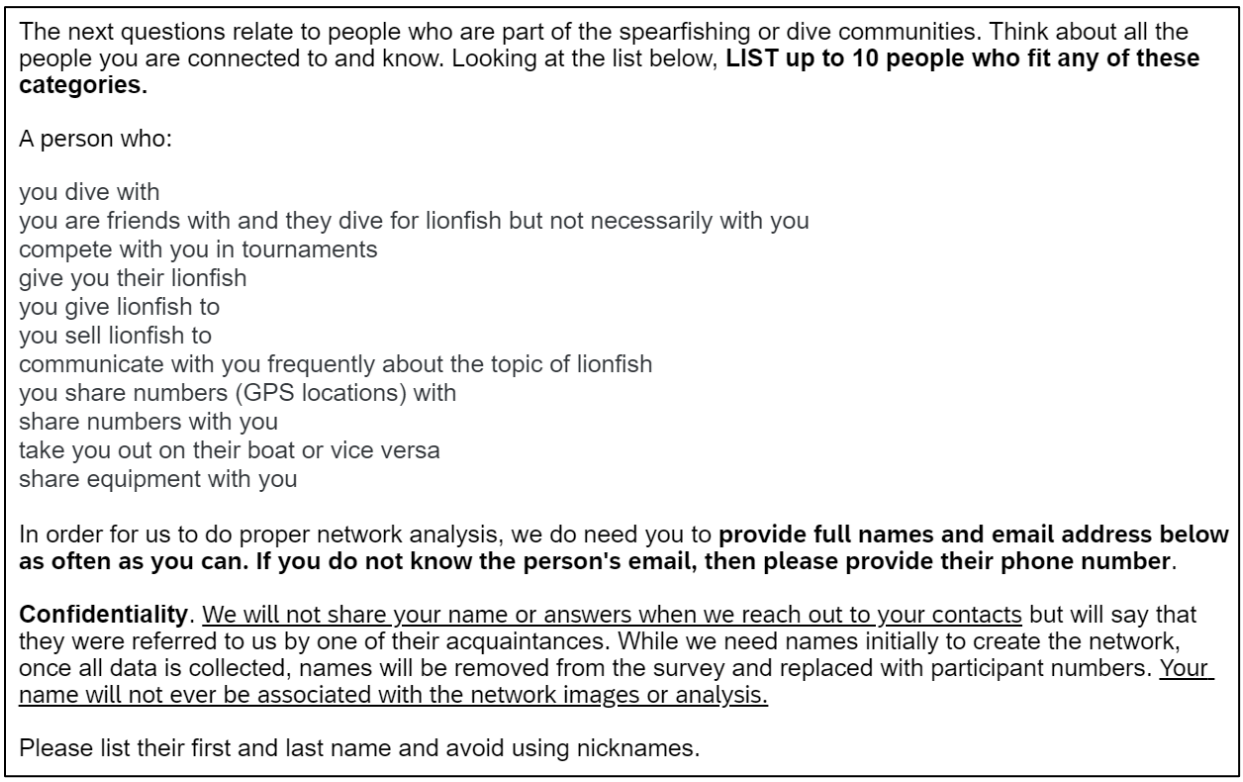
Both instruments assured confidentiality by stating "Your responses will remain completely anonymous. Your name, contact information, and any other personally identifying information will never in any way be released or associated with your responses in reporting of the data. Recommendations you provide for additional survey participants will not be connected to you without your permission."

Question development

SN question development was informed by semi-structured interviews conducted by the first author with 75 lionfish hunters throughout Florida who were contacted at lionfish tournaments, festivals,

and cook-offs. During these interviews, the first author piloted SN questions, including “Who else do you know who is involved in lionfish removal?” and follow-up questions about these relations, such as “How close are you to them on a scale of weak, medium, or strong?”, “How often do you talk to them?”, and “How often do you dive with them?”. These interviews also informed what types of ties were relevant and meaningful to lionfish hunters, such as whether they dive together, share information about fishing spots or “numbers” with each other, or go out on each other’s boats.

SN questions appeared in the second half of the survey after participants had answered questions about their lionfish removal activities and motivations. This section of the questionnaire began with a name generator question and a list of examples for the types of contacts they should list (Figure 4.2).


The next questions relate to people who are part of the spearfishing or dive communities. Think about all the people you are connected to and know. Looking at the list below, **LIST up to 10 people who fit any of these categories.**

A person who:

you dive with
you are friends with and they dive for lionfish but not necessarily with you
compete with you in tournaments
give you their lionfish
you give lionfish to
you sell lionfish to
communicate with you frequently about the topic of lionfish
you share numbers (GPS locations) with
share numbers with you
take you out on their boat or vice versa
share equipment with you

In order for us to do proper network analysis, we do need you to **provide full names and email address below as often as you can. If you do not know the person's email, then please provide their phone number**.

Confidentiality. We will not share your name or answers when we reach out to your contacts but will say that they were referred to us by one of their acquaintances. While we need names initially to create the network, once all data is collected, names will be removed from the survey and replaced with participant numbers. Your name will not ever be associated with the network images or analysis.

Please list their first and last name and avoid using nicknames.

Figure 4.2 Instructions for answering the SN name generator question

Survey distribution

Because the lionfish hunting community is composed of many individuals and it was impossible to obtain complete contact information for all individuals at the outset, we intended to perform a partial

SNA and employ snowball sampling to trace nodes not included in our original contact list. Between June and October of 2021 an online structured survey was sent to 667 contacts who were affiliated with hunting invasive lionfish in Florida by diving and spearfishing. 590 contacts originated from Florida Fish and Wildlife Conservation Commission's roster of people known to be involved in lionfish hunting through participation in events such as the Lionfish Challenge, which is a multi-month competition to remove as many lionfish as possible in Florida. An additional 25 contacts were sent the survey who were not among FWC's contacts but had been interviewed about their involvement in lionfish hunting by the first author during an earlier phase of research. Another 52 new contacts were included whose names and contact information were provided by initial respondents who answered the name generator questions in this survey. Half of all potential respondents were randomly selected to be sent a version of the survey in which an example of a SN map was included in the introduction (hereafter, the "map group"), while the other half of the contacts received the survey without the example SN map (the "no map group"). In total, 322 contacts were sent the survey with the map and 331 without the map. Although half of the contact list was sent each survey, the final number of people contacted were not equal between groups due to unforeseen email bounces. All contacts were sent an email with the survey link except for 14 who were snowball contacts and whose referees only provided phone numbers. These 14 contacts were sent text messages.

To weed out respondents who did not have experience required to answer the survey, the first question asked whether they had spearfished in the last two years. Seven people responded "No" and were not included in the subsequent analysis, including response rates noted below. Eight more did not complete enough questions to conduct meaningful analysis and were also removed from the data but are included in the response rate. Combining the Map group and the No Map group, the overall response rate was 29% (n = 194). This includes respondents who at least answered the first question as "Yes" but may or may not have completed the rest of the survey. The response rate for just the Map group was 29% (n = 94) and for just the No Map group was 30% (n = 100). The overall completion rate was 86% (n = 167).

The completion rate for just the Map group was 81% (n = 76) and for the No Map group was 90% (n = 91). These response rates did not significantly differ (z = -1.79, p = .07). Some incomplete responses were included in analysis because they answered enough of the survey to inform research questions, for a total of 186 analyzed responses. Of the contacts who were sent the survey link in a text message, one responded, and they had received the version of the survey with the map included.

Analysis

Responses were analyzed using Statistical Package for the Social Sciences (SPSS) software. Tests involving dichotomous independent and dependent variables, such as whether respondents who received an example map included at least one network contact, were analyzed using Pearson Chi-square tests to measure significant difference. Mann-Whitney U tests were used to test for significant difference between the Map group and the No Map group in continuous variables, including the number of SN contacts provided and the amount of time spent on the introduction page of the survey, with effect size measured using eta-squared. Z-tests were used to compare the number of different types of ties provided by the No Map group and the Map group.

Results

Impact of example map on responses to social network questions

Nineteen percent (n = 35) of participants across both groups replied that they did know someone who fell into the name generator categories but then left the name generator and tie questions unanswered. Thirty-nine percent (n = 73) provided at least one contact name and 37% (n = 68) claimed they did not know anyone.

The inclusion of an example map had no significant impact on the quantity of respondents who admitted knowing someone who fit into the name generator categories, provision of at least one SN contact, or the number of SN contacts provided (Table 4.1). There was no significant difference in respondents' provision of at least one contact name between those who received a map and those who did

not, even when combining those who claimed to not know anyone and those who claimed to know someone but did not provide any names.

Table 4.1 Analyses comparing the Map group versus the No Map group and their answers to social network questions

Mann-Whitney U is abbreviated to *U*

Test variable	**Map**		**No Map**		**Analysis**
	Count	**%**	**Count**	**%**	
Answered "yes" to "Do you know anyone who fits any of the categories above?"	***n = 83*** 46	55.4	***n = 93*** 61	65.6	$\chi^2 = 1.103$, $df = 1$ $p = .294$
Provided at least one contact name	***n = 83*** 31	37.3	***n = 93*** 42	45.2	$\chi^2 = 1.903$, $df = 1$ $p = .168$
	Median	**IQR**	**Median**	**IQR**	
Number of SN contacts provided	*n = 31* 3.0	2.0 – 5.0	*n* = 42 2.50	1.0 – 8.5	$U = 635$ $p = .855$
Time spent on intro (where example map was shown)	*n = 89* 28.25 seconds	16.0 – 59.8	*n = 97* 19.42 seconds	9.6 – 43.8	$U = 5221$ $p = .014$* $\eta^2 = .033$

The only significant difference, with a small affect size, in the behaviors of respondents was the amount of time spent on the introduction page of the survey, which is where the example map was shown (Table 4.1).

Impact of example map on types of social network ties

Results show that for all tie types there was no significant difference in the number of respondents who provided specific network ties between the Map and No Map groups (Table 4.2). This was analyzed with the test variable being at least one instance of each tie type.

Gender

Comparing respondents who identified as male ($n = 55$) versus female ($n = 17$), 41% of males And 51.5% of females provided at least one contact name and did not significantly differ ($\chi^2 = 1.184$, $df = 1$, $p = .277$). Male and female respondents also did not differ in the number of network contacts they

Table 4.2 Comparison of the proportion of Map versus No Map groups' provision of specific types of ties.

Tie Type	**Map** ***n = 46*** Count	%	**No Map** ***n = 62*** Count	%	**Chi-Square (Likelihood ratio) and significance (two-tailed, *df* = 1)**	
This is one of the primary people I dive with	31	67.4	36	58.1	$\chi^2 = .98$	$p = .322$
I spend time with this person outside of diving together	23	50.0	35	56.5	$\chi^2 = .44$	$p = .506$
I have a close relationship with this person	22	47.8	32	51.6	$\chi^2 = .15$	$p = .697$
I helped this person when they first began lionfish hunting	14	30.4	18	29.0	$\chi 2 = .03$	$p = .875$
This person helped me when I first began lionfish hunting	13	28.3	19	30.6	$\chi^2 = .07$	$p = .788$
I go diving on this person's boat	14	30.4	22	35.5	$\chi^2 = .304$	$p = .581$
This person comes diving on my boat	16	34.8	16	25.8	$\chi^2 = 1.02$	$p = .314$
I share private numbers (GPS locations) with this person	9	19.6	17	27.4	$\chi^2 = .91$	$p = .342$
This person shares private numbers (GPS locations) with me	10	21.7	16	25.8	$\chi^2 = .24$	$p = .624$
This person helps me sell my lionfish	2	4.30	7	11.30	$\chi^2 = 1.79$	$p = .181$
Other tie (another lionfish diver, friend, or local leader in lionfish removal)	1	2.2	7	11.3	$\chi^2 = 3.69$	$p = .055$

provided, with males ($n = 55$) providing a median of 3 (IQR = 1.0 – 7.0) and females ($n = 17$) a median of 2.0 (IQR = 1.5 – 6.0) (Mann-Whitney $U = 470.5$, $p = .968$).

Reluctance to share alters' personal information

Several respondents wrote remarks about sharing people's personal information either in the entry box for the first name generator question or to an open-ended question at the end of the survey that asked if there was anything else they would like to share:

I'm sorry guys, but I'm not comfortable sharing others' personal information. Sorry about that! Hopefully my other answers can be useful.

I skipped the listing the names of divers I know who hunt lionfish because I felt uncomfortable with that.

I cannot give out info like this.

Following the name generator question and questions identifying specific characteristics of respondents' relationships with these generated names, the next instructions were: "This social network analysis requires peop'e's names in order to investigate how relationships among divers in Florida influence lionfish removal. While your name is needed simply to identify you when other respondents mention your name, once all data is collected, names will be removed from the survey and replaced with participant numbers. Your name will not ever be associated with the network images or analysis. What is your first and last name?" Only one respondent who reached this question did not voluntarily provide their first and last name. Of the 175 participants who answered the name question and reached the name generator questions, 42% provided at least one contact name.

Regarding types of ties reported, the three least reported ties were related to coveted information (sharing GPS locations of fishing spots) or sensitive ("This person helps me sell my lionfish") information. Sharing of fishing spots among spearfishers was intentionally used as an answer choice in the survey instrument to measure closeness of a relationship because this indicates a high level of trust. "This person helps me sell my lionfish" is considered sensitive information because it is technically illegal to sell someone else's lionfish for them without a specific license. Of those who did report a network tie (n = 9) that helps them sell lionfish, in response to the question "Have you ever had a Saltwater Products License (SPL)?", three responded "Yes", one chose "Prefer not to say", three responded "No", and two chose "I don't know what a Saltwater Products License is."

Discussion

Our results show that providing an example SN map does not increase responses to SN questions or provision of names and contact information. This is counter to our hypothesis that providing an interesting visual example of what the data could produce would increase respondents' willingness to

provide information about members of their network. This finding has important implications for SN data collection techniques. For researchers who need to use an example network map to convey important information to respondents about the topic of the survey or to clarify instructions, our findings suggest that it is unlikely that such a visual will influence respondents' answers. On the other hand, for researchers hoping to increase collection of contact information in a SN study, the example map does not seem to help. However, it is possible that in addition to other strategies, such as positioning the map closer to the SN-related survey questions in the survey, provision of the map may be helpful. Time spent on the introduction page of the survey, where the example map was shown significantly differed between the two groups, suggesting that participants who received the map did take time to at least look at it.

To be clear, in addition to the respondents who admitted to knowing people but shared no names we also assume that a large proportion of the respondents who claimed to not know anyone were being untruthful. In other words, there was room to increase responses to SN questions. The study population consisted of divers and spear fishers; these are hobbyists who we expect to know at least one contact who would fall into one of the categories listed in the name generator question. Diving inherently involves other people, whether they are dive buddies, boat captains, other spear fishers, or acquaintances interested in similar activities. In fact, the companionship with these other people has been found to be an important part of enjoyment of and safety during the activity (Dimmock, 2009). Therefore, we find it unlikely that all 37% (n = 68) of respondents who claimed they did not know anyone who fit into those categories were in fact providing accurate data. Upon further investigation into the general reluctance of respondents to provide SN information, regardless of whether they received an example map, there are no indicators differentiating those who provided SN information and those who did not. In a study of university faculty by Smith (2008) women had a higher response rate than men to an online survey. However, gender did not significantly predict provision of at least one contact, nor did it predict the number of contacts.

After reading the name generator instructions, which asked for first and last names and contact information (Figure 4.3), those who chose not to provide this information likely did so either because it

would be burdensome to recall people's names and take time to locate and enter contact information for up to ten people or because they felt uncomfortable sharing their acquaintances' names and contact information. Several participants explicitly stated their discomfort with providing other people's information in their response to free response questions in the survey. Furthermore, all but one respondent provided their first and last names, though more than half did not provide even one contact name, suggesting that they are willing to provide their own personal information, but not other people's. This reluctance is likely a signal that participants are members of tightly knit and/or loyal groups who care about respecting each other's anonymity, a barrier sometimes faced in snowball sampling (Parker and Scott 2019; Waters 2015). This can especially be true for sensitive information. For example, Cho et al. (2020) documented barriers facing contact tracing mobile apps for COVID-19 due to privacy concerns and Dang-Pham et al. (2017) faced sensitivity around collecting SN information about behavioral security, such as sharing passwords and access rights.

The least reported type of tie was "This person helps me sell my lionfish." As it is illegal to sell someone else's lionfish for them, it is likely that those who know the rules understood the implications of the question. In fact, two of the respondents who admitted to having someone help them sell lionfish chose "Prefer not to say" when they were later asked if they had ever had a Saltwater Products License. If they had chosen "No", this would have suggested illegal activity. Illegal use of natural resources is of course a difficult topic to collect information about from individuals (Gavin et al., 2010). Although snowball or respondent-driven sampling is often recommended for identifying hard-to-reach populations such as people participating in drug use and other elicit behavior, it can also be a poor method for contexts that include extremely sensitive information because people may protect their contacts from potentially being outed or facing negative consequences (Waters, 2015). While selling other people's lionfish may not be considered extremely sensitive information, it may be sensitive enough to this group, who is already private about sharing coveted information even with each other, such as the location of fishing spots.

Overall, the spear fisher and diver community may be a culture in which sharing others' information, especially friends and acquaintances' contact information, is taboo or would be a sign of disloyalty. Fishers are known to be private about information. Studies on various types of fishers have shown that information sharing about fishing locations, catch, knowledge, and experiences is often limited to select fishermen (Palmer, 1991; Palsson, 1982). This cultural norm may explain the reluctance of many respondents to share SN information. However, it is for this same reason that SN research on fishers is needed to better understand the factors influencing fishing success (Turner et al., 2014). Social networks and information sharing among fishers are an important factor to consider when measuring fishing success. A SN study on lobster fishermen by Turner et al. (2014) successfully collected data from 90% of the SN by conducting interviews in which they asked fishers which other fishing vessels they shared information about fishing locations and catch with. The interview first relied on fishers to recall this information on their own and then showed the participant a roster of active fishing vessel at the port. While this method may have worked better than an online survey for collection of data on lionfish hunters on a case-by-case basis, it would have been infeasible given the size of the lionfish diver community, which consisted of an initial contact list of more than 700 respondents. We encourage SN researchers to build on our findings and identify creative ways to collect SN data effectively and efficiently on large groups.

Several limitations should be noted when interpreting our results. First, results are most relevant to the context of this population, which hold unique cultural norms and perceptions that may affect their participation in the survey and willingness to provide SN information. Other groups may behave differently when filling out the survey. Second, our survey software did not track whether a contact opened the survey link from the email. This means we do not know how many people opened the link, read the introduction to the survey detailing the SN component, and did not answer even the first question. Thus, our analysis and interpretation is based only on those who answered at least one question. We recommend that future studies testing similar elements of survey design and efficacy use a tool that

reports the survey link being opened in order to draw conclusions about whether or not the information, such as an example SN map, provided in the introduction deters respondents from even beginning to take the survey. And finally, this study relied on name generation and snowball sampling rather than a roster of predetermined names. Providing an example SN map in a survey that uses a roster approach may yield different behavior from respondents.

Conclusion

Our study demonstrates that respondents' willingness to provide contact information of their acquaintances is a clear barrier to SN data collection, even when respondents are willing to provide their own personal information. Furthermore, while providing an example SN map does not affect the types of SN ties respondents share, it is not an effective strategy for convincing reluctant respondents to share contact information about their friends and acquaintances. Though this strategy was unsuccessful, we emphasize the need for survey design strategies that improve willingness to provide alters' contact information.

CHAPTER 5: CONCLUSION

Findings from my dissertation contribute to the broader body of knowledge on pro-environmental behavior, invasive species control, and social network research methods. They advance our understanding of pro-environmental behaviors related to lionfish control and underscore opportunities for improved social network data collection. Chapters 2 and 3 provide important findings for management of lionfish in Belize and Florida. These findings also help inform lionfish control strategies in the rest of the invaded range, including the Mediterranean Sea (Azzuro et al. 2017). More broadly, conclusions contribute new insights into pro-environmental behaviors that facilitate invasive species removal as well as market-based approaches to invasive species management. Finally, Chapter 4 provides experimental evidence that underscores the need for additional research and strategies to effectively collect social network data.

Implications for management and research

Belize's lionfish market and consumption behavior

Chapter 2 provides valuable insights about seafood and lionfish consumption in Belize that informs Belize's lionfish management activities. Belize's CHANS approach to lionfish control has identified a lionfish market as an important management strategy. Our findings showing that the majority of Belizeans and tourists are willing to try eating lionfish means there is opportunity for the lionfish market to grow beyond just those who have eaten lionfish already. This also shows promise for markets for other invasive species given that they are favorable in taste and texture. Findings also identify important barriers to growing the lionfish market, including preferences among Belizeans for snapper and perceptions or beliefs that lionfish is not safe to eat among Belizeans and tourists. Tourists' higher willingness to try lionfish and lower food neophobia also highlight the opportunity for marketing unique and sustainable foods to tourists in Belize. A conceptual framework that fills in the research questions depicted in Figure 1.2 is shown in Figure 5.1.

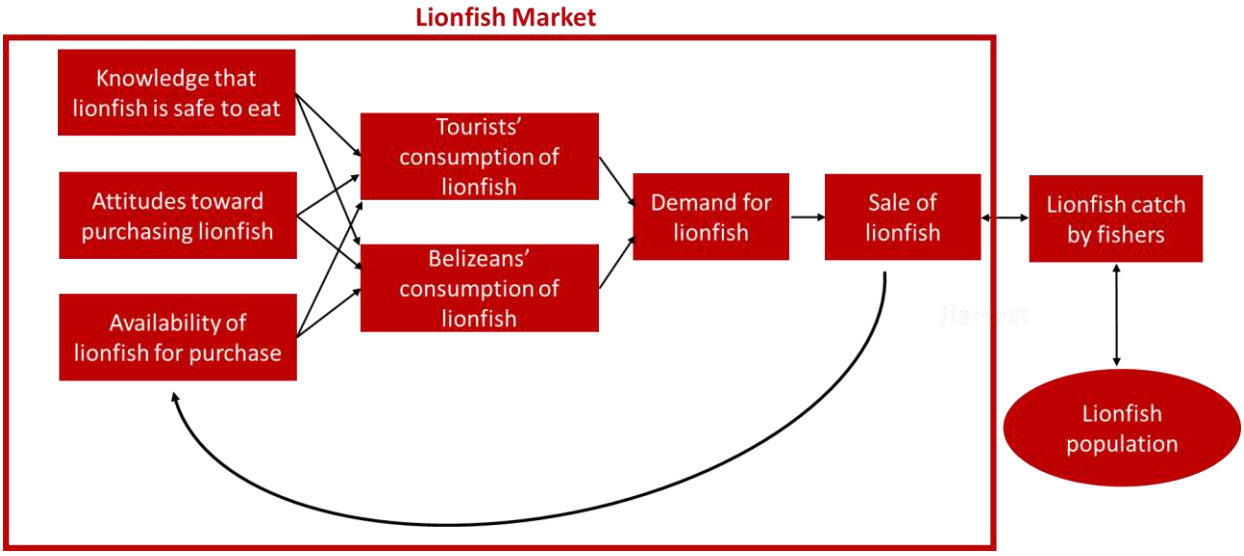


Figure 5.1 Conceptual framework showing how findings presented in Chapter 2 help inform the CHANS framework developed for strategic management of lionfish in Belize

By identifying factors that influence consumers' decision to eat or not eat lionfish, management efforts can focus on removing barriers, such as by increasing communication about lionfish being edible and safe to eat. It may be pertinent to communicate the difference between venomous and poisonous in order to correct misperceptions as well.

In addition, the Belize National Lionfish Management Strategy (Chapman et al., 2019) presented a study of restaurants showing that a barrier to engaging consumers is consistent supply. Adding this factor into the framework illuminates an important feedback loop between supply and demand, shown by the arrow from "Sale of lionfish" to "Availability of lionfish for purchase". Fishers will supply lionfish if there is someone to sell it to, which means, unsurprisingly, that demand for lionfish is key, but consumers cannot purchase lionfish or try it if it is not available where they purchase seafood. This feedback loop is not unique to Belize. The success of lionfish hunters in Cozumel in depleting the local lionfish population led to the demise of the lionfish market in the area (Malpica-Cruz et al., 2021). A similar dynamic is seen in Florida with lower lionfish densities, or availability of lionfish in the ecosystem, causing some commercial lionfish hunters to be unable to sustain a profitable level of lionfish harvest, as discussed in Chapter 3.

Finally, our finding that the knowledge that lionfish meat is safe to eat is a significant predictor of willingness to consume lionfish is important for understanding pro-environmental behavior. Existing understanding of pro-environmental behavior posits that attitude toward a behavior and other variables such as subjective norms are more important than knowledge or serve as mediators between knowledge and the behavior (Ajzen, 1991; Kollmuss & Agyeman, 2002; Liu, Teng & Han, 2020). In this case, the amount of knowledge was not a significant predictor of willingness to eat lionfish. However, the specific piece of knowledge about lionfish being safe to eat by itself was a significant predictor. This underscores the importance of context when understanding a particular behavior and what specific types of knowledge, beliefs, or misperceptions may significantly influence a person's behavior.

Almost half of Belizeans did not know that lionfish was safe to eat, compared to 75% of tourists who did. This misperception is possibly due to communication about lionfish emphasizing lionfish as a dangerous invasive species. While their venomous nature is fodder for news stories, the emphasis on this characteristic can be detrimental to promoting consumption of lionfish. This case study should serve as a caution to other market-based efforts in the invaded range to be intentional about marketing lionfish as an edible food fish that is safe to eat.

Lionfish hunters and the lionfish market in Florida

Market-based approaches have become a central strategy for controlling lionfish populations (Chapman et al., 2016; Ulman et al., 2021) and some other invasive species (Pasko & Goldberg, 2014). However, concerns about whether this will incentivize people to perpetuate the invasion have yet to be addressed. Our finding that lionfish hunters are largely motivated to remove lionfish to protect the reef and have strong personal norms to kill lionfish in order to do so should assuage concerns that, given the current circumstances, creating a market for lionfish in Florida may create perverse incentives to perpetuate the invasive population (Pasko & Goldberg, 2014). Even the lionfish hunters who sell lionfish largely do so for prosocial reasons, such as so more people can try it or because the lionfish market is an important strategy for controlling the invasion. Still, financial incentives play a role in lionfish removal in

Florida. In keeping with the logic behind a market-based approach to management, lionfish hunters who sell lionfish or who are primarily motivated to make money off lionfish do kill significantly more lionfish than other lionfish hunters. These findings show that given a context in which lionfish hunters are motivated to sell lionfish and have a willing market, a market-based approach can increase lionfish removal among profit-motivated hunters or among those trying to subsidize their spearfishing or diving hobby. However, it is difficult to make a profit from lionfish, as indicated in interviews, which causes few people to do so. Engagement of lionfish hunters in lionfish removal may be more effective and efficient if it appeals to their existing motivations, or what is already working. For one, when abundance of lionfish is low, it may be more appropriate to encourage lionfish hunting as a way of subsidizing the hobby of diving or spearfishing among recreationists or as an addition to other targeted species among commercial spear fishers.

Motivation is a key factor determining the success of conservation actions that depend on pro-environmental behaviors. Importantly, not only are there very few lionfish hunters who are primarily motivated by money, but they also can only justify the investment it takes to commercially harvest lionfish if there are enough lionfish in the water to support a profitable harvest. This reflects the same feedback loop discussed in Chapter 2 and by Malpica-Cruz et al. (2014): availability of lionfish in the water and in the market must be sufficient to maintain both supply and demand.

These conclusions are important for lionfish management that depends on spearfishers for lionfish removal, which currently is the case throughout the invaded range (Morris et al., 2011, Chapman et al., 2019). Given that lionfish populations are not currently maintained like other fisheries and management does not ensure persistence of the population, management based on a lionfish market must be careful to: 1.) not jeopardize the livelihoods of fishers who become reliant on lionfish and 2.) effectively engage lionfish hunters based on their various motivations beyond profit for long-term removal efforts. When lionfish populations decrease for any reason to a point where lionfish hunters struggle to make a profit, we will need to rely on other lionfish hunters who are not primarily motivated

by profit to maintain lionfish control in the long-term as populations fluctuate. This may be problematic if these fluctuations cause a collapse of the market, as in the case of Cozumel (Malpica-Cruz et al., 2014).

Findings from this study provide insight into a market-based approach to control an invasion in a system with a feedback loop which makes it more difficult for supply to meet the demand. The lionfish invasion in Florida is a CHANS in which the management strategies of spreading awareness about lionfish and promoting recreational and commercial harvest of lionfish have successfully created a negative feedback loop. Sinclair, Brown and Lockwood (2020) describe this type of CHANS as a recipient region coupling with a negative feedback loop, meaning a system in which a non-native species has been introduced and become destructive to cultural or recreational activities, which instigate eradication efforts that successfully limit abundance of the invasive species by promoting awareness and facilitating control activities. This contrasts with CHANS defined by positive feedback loops, in which non-natives become positively perceived and seen as novel with decreased abundance and increased familiarity, causing people to intentionally increase population or dispersal.

Similar to local responses to invasions in which invasive species negatively impact private land, recreational activities and other culturally important resources and habitat (Niemiec et al., 2017; Seekamp et al., 2016), the stakeholders of the fisheries and habitats damaged by lionfish – divers and spear fishers – are now motivated to protect them by actively harvesting the destructive species. Sinclair et al. (2020) emphasize the need for research on feedback loops in invasion processes to more clearly illustrate or correct their assumptions. The case of lionfish hunters harvesting lionfish in Florida to eat and to sell provides such illustration and underscores the role of recreationists in removing an invasive species from the ecosystem they depend on for recreational enjoyment. It also illustrates an ideal fit of engaged stakeholders with the desired behavior: the activity of removing lionfish to protect the habitats and species they value is the very same activity they seek to protect from lionfish – diving and spear fishing. The case study in Florida thus illustrates the ideal balance between engaging people in a behavior primarily for pro-environmental reasons and attaining enjoyment, fulfillment, and sometimes financial

rewards for doing so. The key is that protection of the reef and personal norms motivating lionfish hunters to protect the reef are the dominant motivation, thus ensuring that the feedback loop remains negative rather than positive.

The role of the market in Florida potentially represents an additional feedback loop: decreases in the lionfish population make profit more difficult among those who sell lionfish, thereby decreasing the efficacy of a market for incentivizing profit-motivated lionfish hunters. Further research on the activities of profit-motivated lionfish hunters and their engagement in lionfish removal when the lionfish population decreases is needed to better understand this feedback loop. For example, if most profit-motivated lionfish hunters divert their attention to other forms of income when lionfish abundance is low, it may be that these hunters are most appropriate to engage when lionfish are abundant and the invasion is at a peak and the large quantities of lionfish they are capable of removing is required to protect the ecosystem.

Opportunities to improve social network data collection

Social network research offers a novel approach to understanding social-ecological systems because it accommodates the reality that everything in a system – social or ecological – is connected in some way. It also provides an additional tool for understanding contextual factors, like community and relationships, that influence human behavior. However, conducting this type of research sometimes requires more rigorous data collection than other social science methods, which can be a barrier to integrating it into conservation research. In our attempt to conduct a social network analysis of the whole network of lionfish hunters in Florida, we learned valuable lessons for social network research. First, our low response rate to social network questions demonstrates the difficulty of collecting this type of information. Written-in comments about feeling uncomfortable sharing other people's information suggest this is likely why people choose not to share this information. Our hypothesis that providing an example social network map would increase responses to these questions was not met. On the other hand, providing an example map also did not skew the types of social contacts people provided; thus, if a

researcher needs to include a social network visualization in their survey, this suggests that it will not bias responses.

Our lack of success in collecting sufficient network data or improving responses to social network questions means more research is needed to inform best practices for social network data collection methods. This is especially true for large networks with unclear boundaries in which snowball sampling is needed or online surveys are the most efficient data collection tool. If we are unable to collect this type of data in an efficient manner, important contributions from social network analysis to conservation and other fields will be missed.

Personal Reflection

I embarked on my dissertation journey with the goal of exploring pro-environmental behaviors and social network characteristics that influence these behaviors in order to help inform management efforts to control invasive lionfish. Humans are complicated. There are infinite pathways to go about researching human behavior. Throughout my journey as a doctoral student, I have had the privilege of exploring a variety of disciplines, including human dimensions of natural resources, cognitive anthropology, education, sociology, and social psychology, just to name a few. I have also learned methods from experts in these various disciplines, including various methods for qualitative and quantitative data collection and analysis. I have become comfortable with being the outsider: the natural resources person in a room of educators or the social scientist in a room of ecologists. Though being in these vulnerable positions can sometimes be difficult for the ego, it is by learning from other types of scientists and breaking down research questions using new theories and perspectives that research becomes stronger. To face the threats that our conservation targets face in the Anthropocene, we must abandon our silos, make new connections across scientific disciplines, and collaborate with other types of scientists.

The need for collaboration to solve conservation issues does not end with interdisciplinary science, however. We must also work with practitioners who work on these problems daily as well as the

stakeholders who are directly connected to the conservation threats and targets. The conceptualization of our research on the Belize lionfish market was possible through collaboration with local practitioners at Blue Ventures, who in turn work with dozens of other non-governmental organizations and government agencies on lionfish control. Similarly, research questions about lionfish hunters in Florida were developed in collaboration with FWC and were further informed by leaders and scientists involved in control efforts at University of Florida, NOAA, REEF, and Okaloosa County. The nature of my research also involved immersion in the local context where these studies were conducted. While I did not collect the data on Belize lionfish consumption myself, I did conduct other research in Belize for my master's degree while my colleagues Julie and Phil travelled the country and asked hundreds of people questions about seafood and lionfish. I bought lionfish from fishmongers or from fishers off the beach, volunteered at the fish festival where we lived in Punta Gorda, and watched fishers fillet lionfish on the dock in Tobacco Caye. You cannot replace the insights and understanding gleaned from living in the context upon which your findings are based.

The same was true for Florida's lionfish hunting community community. I am a native Floridian and grew up in a recreational fishing family, but also spent the summer of 2019 travelling to as many lionfish tournaments as possible throughout the state. I spoke to anyone who would talk to me: chefs, Whole Foods representatives, wholesalers, fellow researchers, directors of nonprofits, tournament organizers, inventors of robots that vacuum up lionfish, charter captains, novice lionfish hunters, infamous lionfish hunters, and divers whose lives revolved around hunting lionfish. I met a diver who had a lionfish tattoo, and another who gave me a free scuba diving lesson in hopes that they would create yet another lionfish hunter. As an honorary member of the lionfish community, most of the notifications I receive on social media are about someone's latest lionfish catch, tournament, or scientific finding. The knowledge and understanding gained through immersion in this community is not something that can be easily communicated through science. These stakeholders are invested in their purpose beyond what a dissertation can convey.

These experiences have demonstrated to me the importance of using mixed methods, when possible, in my research on human subjects. My interviews and time in the field enrich my research and the story I tell. The quantitative data I have collected through surveys by itself cannot capture a complete picture. In fact, our scientific endeavors never truly describe the whole story. Our pursuit of objectivity and large quantities of data will always fall short of true reality. This quote by anthropologist Gregory Bateson captures a bit of my post-positivist philosophy about scientific research:

"The continuum of nature is constantly broken down into a discontinuum of variables in the act of description."

By remembering that we can only ever measure one small piece of nature at a time (I include humans in the concept of "nature") from a particular position or perspective, at a particular time, using a particular methodology, I remain humble as a scientist. It is my job to investigate nature's social-ecological systems in a way that produces findings that are as close as possible to describing true reality or fully relating the experiences of my research subjects. Approaching research questions through an interdisciplinary lens, using holistic frameworks like CHANS, collaborating with a fellow coder to interpret qualitative data, and using multiple methods to triangulate my findings is the best way I've found so far to understand nature. As a researcher, I will continue to learn and apply methods that help us capture various ways of knowing, including ethnographic and participatory methods, and that enable me to do justice to the stories of my research subjects. I encourage other scientists to do so as well

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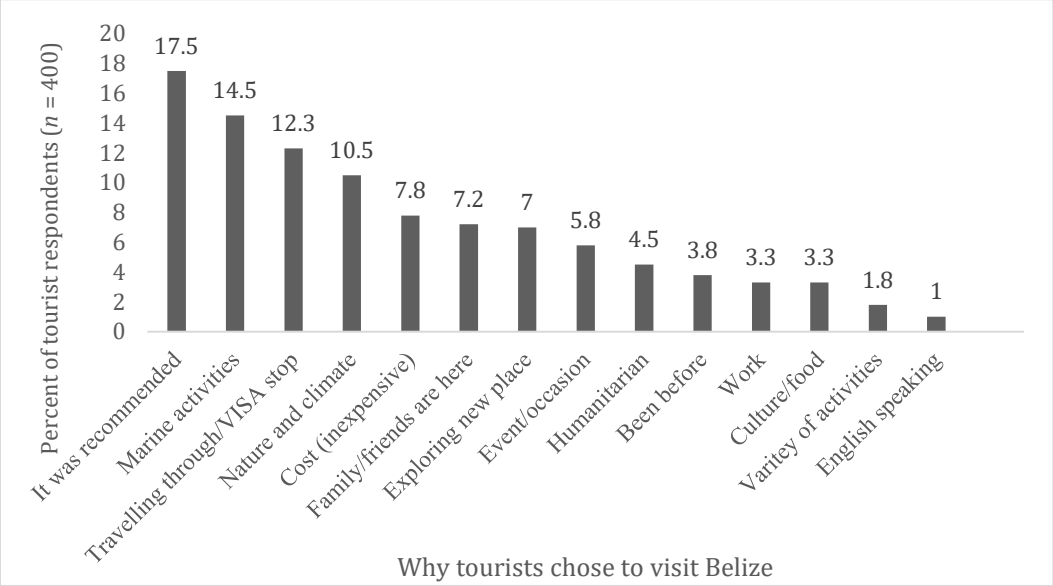
APPENDIX A: CHAPTER 2 SUPPLEMENTARY TABLES AND FIGURES

Appendix Table A1. Sociodemographic data on Belizean and tourist survey participants, including gender, age, cultural identity, place of residence, level of education, occupation, visitation of Belize and coastal towns, and participation in marine activities.

Belizean respondents' socio-demographics	%	**Foreign tourist respondents' socio-demographics**	%
Gender (*n* = 400)		**Gender (*n* = 400)**	
Male	47.0	Male	44.0
Female	53.0	Female	56.0
Age (*n* = 400)		**Age (*n* = 400)**	
18-24	28.7	18-24	15.0
25-34	29.0	25-34	42.3
35-44	18.8	35-44	16.3
45-54	12.8	45-54	13.3
55+	10.8	55+	13.3
Cultural identity (*n* = 400)		**Home country/region (*n* = 400)**	
Mestizo/Latino	47.0	US Coastal	39.3
Creole	23.0	US Inland	20.3
Mayan	10.8	Europe	28.7
Garifuna	9.0	Canada	4.5
East Indian	5.0	Australia/New Zealand	1.8
Caucasian	0.5	South America	1.5
Other/Unsure	4.8	Mexico	1.5
Area of residence (*n* = 400)		Central America & Caribbean Islands	1.3
Inland	38.0		
Coastal	62.0	Asia	.8
District of residence (*n* = 400)		Africa/Middle East	.5
Belize	28.0	**Times visited Belize (*n* = 400)**	
Cayo	22.0	First time	80.3
Orange Walk	16.0	Once before	8.8
Corozal	14.0	2-3 times before	5.3
Stann Creek	10.0	4-6 times before	3.8
Toledo	10.0	7 or more times before	1.8
Level of education (*n* = 400)		**Level of education (*n* = 400)**	
Pre-school	5.0	High school	13.8
Primary school	32.0	Associates degree	19.3
Secondary school	32.0	Bachelor's degree	39.5
Associates degree	22.8	Masters/PhD	27.5
Bachelor's degree	6.3	**Occupation (*n* = 399)**	
Masters/PhD	1.3	NGO/Government/Large business	27.3
None	0.5		
Occupation (*n* = 400)		Retail/sales/small business/real estate	29.3
Student	10.0		
Housewife	8.3	Education/nursing	14.2
Domestic	5.3	Student/not working/retired	23.5
Unemployed	4.8	Manual labor/technician	3.5
Construction	3.8	Self-employed/prefer not to	2.0
Teachers	3.5	**Participated in marine activity (n=399)**	
Farmers	3.3		90.5
Fishermen	2.5	**Identify as a diver or snorkeler (*n* = 400)**	

Occupation associated with tourism, fishing, or restaurant? (*n* = 400)			85.5
No	87.3	**Visiting coastal town (*n* = 400)**	
Yes	12.8	Visiting one coastal town	45.8
		Multiple coastal towns	49.3
		No coastal towns	5.0

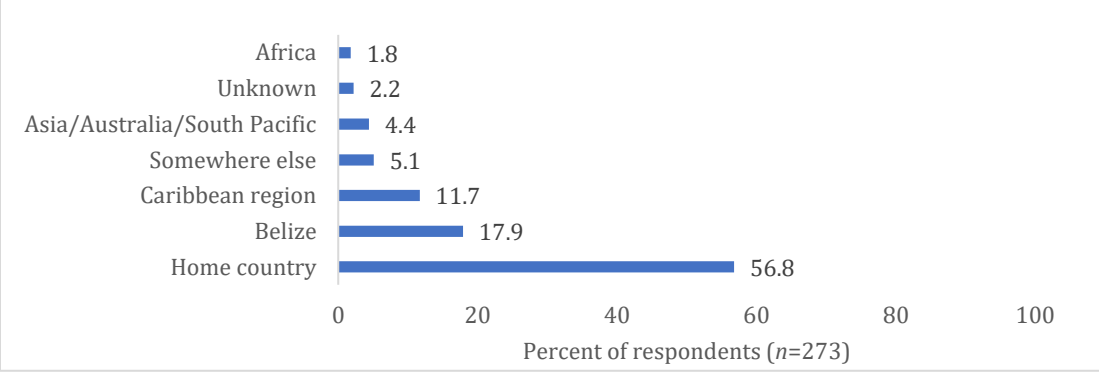


Appendix Figure A1. Reasons tourist respondents stated for why they chose to visit Belize, shown as percentage of the tourist sample group.

Appendix Table A2. Belizean and tourist survey responses to questions about seafood consumption behaviors and preferences. Some questions pertain only to Belizeans or only to tourists.

Survey question	Belizeans		Tourists	
		%	Count	%
Do you eat seafood? ("Yes")	***n = 400***		***n = 400***	
		91.8	367	91.8
How often do you eat seafood at home/in your home country? (of those who eat seafood)	***n = 367***		***n = 367***	
Never		0.4	10	2.7
Once/2-3 months(BZ survey); a few times a year (tourist survey)		3.4	19	5.2
1-2 times/month		14.4	122	33.2
1-2 times/week		17.8	205	55.9
>3 times/week (BZ survey); once/day (tourist survey)		10.0	11	3.0
How often do you eat seafood at a restaurant? (of those who eat seafood) Belizeans only	***n = 367***			
Never		12.9		
Once/2-3 months		12.4		
1-2 times/month		13.6		

1-2 times/week	6.0		
>3 times/week	1.0		
How often have you or do you plan to eat seafood in Belize? (of those who eat seafood) Tourists only		***n = 367***	
Never		20	5.4
Every 3+ days		77	21.0
Every other day		126	34.3
Once a day		144	39.2
How long is your trip? Tourists only		***n = 400***	
1-4 days		57	14.2
5-7 days		164	41.0
8-14 days		125	31.3
15-30 days		26	6.5
30+ days		28	7.0
What type of seafood have you eaten on your trip? (of those who ate seafood on their trip) Tourists only		***n = 369***	
Fish		49	13.3
Shellfish/conch only		50	13.6
Both		193	52.3
None		75	20.3
Unsure		2	0.5

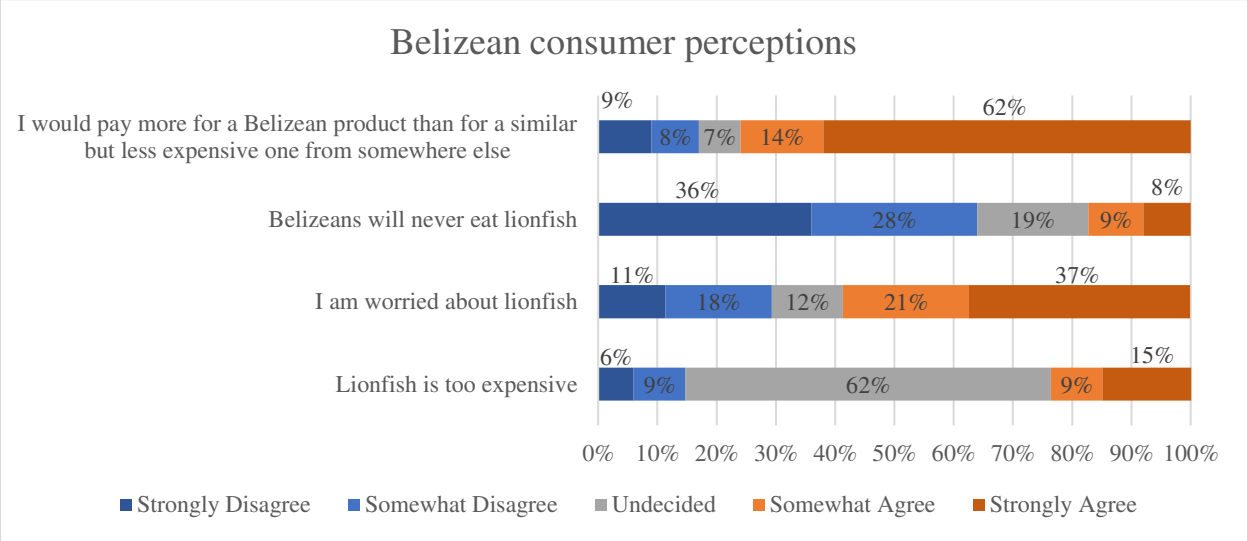


Appendix Figure A2. Of the tourists who had heard of lionfish, percent who indicated each of seven places where they first heard about it.

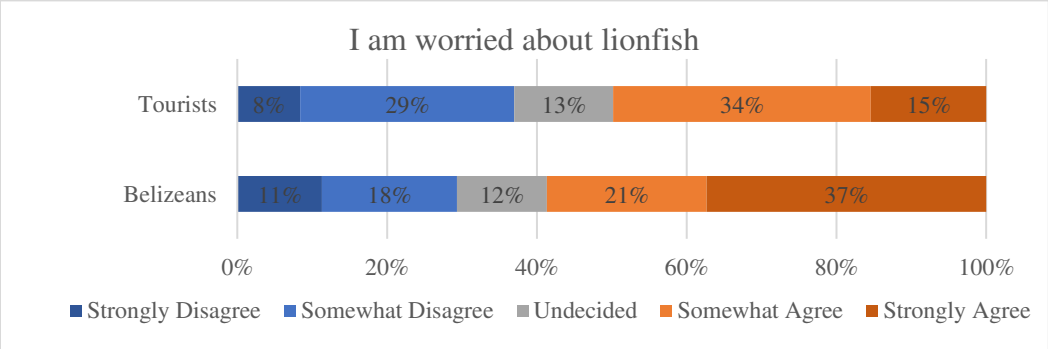
Appendix Table A3. Responses to "Why do you choose to eat seafood?". A * denotes a significant difference between Belizeans and tourists.

Why do you choose to eat seafood?	**Belizeans *n = 363***		**Tourists *n = 367***		**Z score & Significance**		**Effect Size**
	Count	%	Count	%			
Health*	137	37.3	60	16.5	$z = 6.51$	$p < .001$	$h = .48$
Taste	101	27.5	114	31.4	$z = -.96$	$p = .337$	
Fresh or local*	0	0.0	108	29.8	$z = -11.20$	$p < .001$	$h = 1.15$
Prefer/like it	52	14.2	41	11.3	$z = 1.28$	$p = .201$	
Variety*	43	11.7	0	0	$z = 6.80$	$p < .001$	$h = .70$
Culture or religion*	20	5.4	1	0.3	$z = 4.23$	$p < .001$	$h = .36$
To try new things*	3	0.8	32	13.9	$z = -4.99$	$p < .001$	$h = .58$

Can't normally get it*	0	0.0	12	3.3	z = -3.47	p < .001	h = .37
Can't eat red meat*	0	0.0	8	2.2	z = -2.83	p = .005	h = .30
Availability/only option	9	2.5	3	0.8	z = 1.77	p = .077	
Affordable	2	0.5	4	1.1	z = -.81	p = .418	



Appendix Figure A3. Stacked bar chart of Likert item responses to statements about consumer behavior and lionfish among Belizeans (n = 300).



Appendix Figure A4: Stacked bar chart of agreement with the statement "I am worried about lionfish" among Belizeans (n = 300) and tourists (n = 273).

Appendix Table A4. Knowledge, attitude, neophobia, and behavioral intention comparisons between females and males among Belizeans and tourists. "Analysis" includes statistical information specific to the type of test done on the data, including chi-square, Mann-Whitney U tests, and effect size measurements. M denotes Median.

	Belizeans			**Tourists**		
Variable	**Female**	**Male**	**Analysis**	**Female**	**Male**	**Analysis**
Knowledge score	M = 4.0 IQR = 2.0-5.0 n = 130	M = 5.0 IQR = 3.0-6.0 n = 170	U = 13356.5 p = .002* η^2 = .032	M = 5.0 IQR = 3.0-6.0 n = 151	M = 5.0 IQR = 2.8-6.0 n = 122	U = 9287.0 p = .905

Attitude score	M = 16.0 IQR = 12.0-19.0 *n* = 130	M = 17.0 IQR = 13.0-21.0 *n* = 170	*U* = 12458 *p* =.058	M = 20.0 IQR = 17.0-23.0 *n* =151	M = 18.80 IQR = 16.8-22.0 *n* = 122	*U* = 8196.5 *p* = .117
Neophobia score	M = 12.0 IQR = 11.0 - 16.0 *n* = 188	M = 13.0 IQR = 11.0-16.0 *n* = 212	*U* = 21180.0 *p* = *.276*	M = 18.0 IQR = 15.0-20.0 *n* = 224	M = 17.0 IQR = 15.0-20.0 *n* = 176	*U* = 18611.0 *p* = .330
Heard of lionfish	71% *n* = 171	82% *n* = 196	χ^2 = 6.65 *df* = 1 *p* = .01* ϕ = 0.14	67% *n* = 223	69% *n* = 176	χ^2 = 0.19 *df* = 1 *p* = .66
Tried lionfish before	10% *n* = 121	19% *n* = 161	χ^2 = 4.30 *p* = .04* ϕ = 0.12	15% *n* = 151	17% *n* = 122	χ^2 = 0.20 *p* = .66
Willing to try a sample	39% *n* = 109	60% *n* = 131	χ^2 = 11.80 *p* = .003* *V* = 0.22	70% *n* = 128	78% *n* = 102	χ^2 = 1.74 *p* = .42

Appendix Table A5. Binary logistic regression analyzing correct answers to true or false statements about lionfish and the answer of "Yes" to "If you were offered a free sample of lionfish at the market, would you try it?" as opposed to all other respondents, including answers of "No", "Undecided" or missing. Standard errors are in parentheses. Confidence intervals of 95% are listed below the *p*-value for each odds ratio.

Variable	**Belizeans** ***n* = 400**	**Tourists** ***n* = 400**
Lionfish have always been in Belize waters	Exp(B) = .85 *p* = .524 .51 – 1.42 (.26)	Exp(B) = .73 *p* = .39 .36 – 1.48 (.36)
Lionfish are bad for the reef	Exp(B) = .73 *p* = .334 .38 – 1.39 (.33)	Exp(B) = .93 *p* = .85 .45 – 1.92 (.37)
Lionfish are moving into new areas	Exp(B) = 1.20 *p* = .626 .57 – 2.53 (.38)	Exp(B) = .71 *p* = .374 .33 – 1.52 (.39)
Lionfish can't be handled	Exp(B) = .85 *p* = .53 .52 – 1.40 (.26)	Exp(B) = .91 *p* = .753 .52 – 1.61 (.29)
People die from lionfish stings	Exp(B) = .80 *p* = .415 .46 – 1.38 (.28)	Exp(B) = .95 *p* = .859 .55 – 1.64 (.28)

Lionfish threaten Belize's fishing industry	Exp(B) = 1.47 *p* = .260 .76 – 2.87 (.34)	Exp(B) = 1.40 *p* = .284 .76 – 2.61 (.32)
Lionfish meat is safe to eat	Exp(B) = 2.50 *p* = .001 1.47 – 4.26 (.27)	Exp(B) = .1.97 *p* = .022 .1.10 – 3.52 (.30)
-2 Log Likelihood	389.13	347.97

APPENDIX B

Survey instrument for tourists

Screening Questions-
Screening Q1. Are you 18 years of age or older?
[if yes continue; if no thank respondent for their time]

Screening Q2. Is your primary residence not Belize? [if yes continue; if no thank respondent for their time]

Metadata-
Date_____
[dd/mm/yyyy]
Researcher_____
[0:JS 1:other]
Location_____
[0:San Pedro, 1:Caye Caulker, 2:Belize City, 3:Placencia]
Time start_____
[hh:mm]
Time end_____
[hh:mm]

Travel Experiences-
I'm going to ask you a series of questions about your travel experience
Q1. How often do you travel for leisure?
[select one]
3+ times a year [0]
2 times a year [1]
1 a year [2]
1 every 2-3 years [3]
This is my first time traveling [4]

Q2. Is this your first time to Belize?
[select one]
Yes [1]
No [0]

Q3. (if yes) How many times have you visited Belize before?
[open ended]

Q4. How long is your planned trip?
[open ended]

Q5. Why did you choose to travel/vacation to Belize?
[open ended]

Q6. What (if any) activities did you or do you plan on doing during your time in Belize?
SCUBA [0]
Snorkeling [1]
Hiking [2]
Relaxing on Beach [3]
Visit ruins [4]
Fishing [5]
Just passing through [6]
Other [open ended; coded]

Q7. What different towns/cayes have you visited on this trip?
San Pedro [0]
Caye Culker [1]
Placencia [2]
Punta Gorda [3]
Belize City [4]
Hopkins [5]
Other [open ended; coded]

Seafood Consumption-
I'm going to ask you a series of questions about seafood

Q8. Do you eat seafood? (This includes fish, lobster or conch) (*Screening question*)
[select one]
No [0]
Yes [1] (if no continue to Q8.)

Q9. How often do you eat seafood when you travel to the caribbean?
[select one]
At least once day [0]
3-4 times per trip [1]
1-2 times per trip [2]
Never [3]

Q10. What are the reasons you choose to eat seafood? [Select 'primary' one]

Because I believe it is healthy [0]
Because I like the way it tastes [1]

Because it is a more environmentally friendly choice than other meats [2]
Because of cultural reasons [3]
Because I can't normally get it where I am from [4]
It's affordable here in Belize [5]
Other_____ [open ended response; coded]

Q11. Do you have a preferred fish you like to eat?
[open ended; coded]

Q12. Why do you eat [said fish] the most?
[open ended; coded]

Q13. Have you heard of lionfish?
[if yes continue; if no skip to Q23]
No [0]
Yes [1]

Q14. Have you ever tried eating lionfish?
No [0]
Yes [1] (skip to Q10)

Q15. Was that here in Belize?
[select one]
Yes [1]
No [0]

Q16. If it was not in Belize, Do you remember where you first tried lionfish?
[open ended; coded]

Q17. Do you remember when that was?
[open ended]

Q18. Have you eaten lionfish more than once?
[select one]
No [0]
Yes [1]

Q19. Have you ever purchased lionfish?
[select one]
No [0]
Yes [1]

Q20. What made you first want to try lionfish?
Heard it tasted good [0]

Restaurant special [1]
Sponsored event [2]
Party [3]
I'm concerned about the marine environment
I love to eat fish
Other_____ [open ended response; coded]

Q21. When thinking about the first time you tried Lionfish, where you…
[Select one]

One of the first to try it [0]
You tried it after SOME friends/family tried it [1]
You tried it after MANY friends/family tried it [2]
Were you very reluctant to try it [3]

Q23. How much would you pay for a lionfish burger with fries?
[select one]
Would not buy [0]
Other [open ended]

Q24. How much would you pay for a bowl of lionfish ceviche?
[select one]
Would not buy
Other [open ended]

Q25. How much would you pay for a lionfish fillet with two sides?
[select one]
Would not buy
Other [open ended]

Q26. If you were offered a free sample of lionfish at a restaurant, would you try it?
[select one]
No [0]
Yes [1]
Undecided [2]

Q27.Could you tell me why you would not try lionfish?
[open ended]

Level of Knowledge-

Now I want to ask you a few questions about lionfish…

Q28. How much would you say you know about lionfish?

[select one]

None [1]
A little bit [2]
Some [3]
Quite a bit [4]
A lot [5]

Q29. I am going to give you 7 statements, please tell me whether you think they are "***True****" OR "****False****".*
[select one]

True [2]
False [0]
Uncertain [1]

Lionfish have always been in Belize's waters (F)
Lionfish are bad for the reefs (T)
Lionfish are moving to new areas (T)
Lionfish can't be handled (F)
People die from lionfish stings (F)
Lionfish threaten Belize's fishing industry (T)
Lionfish meat is safe to eat (T)

Attitudes and Perceptions-

Q30. Please state how much you AGREE or DISAGREE with the following statements about lionfish.
[select one]
Strongly disagree [1]
Somewhat disagree [2]
Undecided [3]
Somewhat agree [4]
Strongly agree [5]

I would purchase lionfish if I knew that buying it had a benefit for the reef…
I like other fish/seafood too much to buy lionfish…
I would purchase lionfish if I knew buying it benefited local fishermen…
Even if lionfish was commonly available I probably wouldn't buy it…
Lionfish is currently too expensive...
I would purchase lionfish if it was regularly available…
I am worried about lionfish…
Others??

[if they somewhat or strongly agree] ask the following statement

Q 30a. Since you agreed, could you tell me why you are worried?
[open ended]

Q31. Please state how much you AGREE or DISAGREE with the following statements about your eating habits....
[select one]
Strongly disagree [1]
Somewhat disagree [2]
Undecided [3]
Somewhat agree [4]
Strongly agree [5]

I do not trust new foods… (attitude)
I will eat almost anything...
When considering what food to buy my main consideration is how much it costs… (attitude)
Fish/seafood? is too expensive… (attitude)
I am curious to try new foods… (attitude)
I like to try new recipes

Information Networks-

Q32. What influences you the MOST on choosing where to traveling when traveling abroad?
[select one]

Friends/family suggestions [0]
Cost [1]
Variety of activities [2]
Location [3]
Safety [4]
Been there before (familiarity) [5]
Social media (fb, twitter, etc.) [6]
Travel agent [7]
Other [open ended response; coded]

Sociodemographic-

Finally, I would like to ask you some questions about yourself...

[researcher selects]
Female [0]
Male [1]

Q33. What is your age?

[Allow range]
18-150

Q34. What country/state/provence are you from?
Other [open ended; coded]

Q35. What is your occupation?
[open ended response; coded]

Q36. What is the primary job that provides income for your household?
[open ended response; coded]

Q37. What is the highest level of formal education you have achieved?
[choose one]

No school [0]
High school [1]
Associate's degree [2]
Bachelors [3]
Masters/Ph.D. degree [4]

APPENDIX C

Survey instrument for Belizeans

Screening Questions-
Screening Q1. Are you 18 years of age or older?
[if yes continue; if no thank respondent for their time]

Screening Q2. Are you a resident of Belize? (1 year or more)
[if yes continue; if no thank respondent for their time]

Metadata-
Date_____
[dd/mm/yyyy]
Researcher_____
[0:JS 1:PK 2:other]
Location_____
[0:Belize City, 1:Belmopan, 2:Benque, 3:Corozal, 4:Dangriga, 5:Orange Walk, 6:Punta Gorda, 7:San Ignacio, 8:San Pedro, 10: Santa Elena 11:Sarteneja]
Time start_____
[hh:mm]
Time end_____
[hh:mm]

Seafood Consumption-

I'm going to ask you a series of questions about seafood

Q1. Do you eat seafood? (This includes fish, lobster or conch) (*Screening question*)
[select one]
No [0]
Yes [1] (if no continue to Q8.)

Q2. How often do you eat seafood at home?
[select one]
Three or more times in one week [0]
Once or twice in one week [1]
Once or twice in one month [2]
Once every 2 to 3 months [3]
Never [4]

Q3. How often do you consume seafood at a restaurant?
[select one]
Three or more times in one week [0]
Once or twice in one week [1]
Once or twice in one month [2]
Once every 2 to 3 months [3]
Never [4]

Q4. What are the reasons you choose to eat seafood? [Select 'primary' one]

Because I believe it is healthy [0]
Because I like the way it tastes [1]
Because it is a more environmentally friendly choice than other meats [2]
Because of cultural reasons [3]
Because it is commonly available [4]
Other_____ [open ended response; coded]

Q5. What type of fish do you eat the most?
[open ended; coded]

Q6. Why do you eat [said fish] the most?
[open ended; coded]

Q7. Have you heard of lionfish?
[if yes continue; if no skip to Q23]
No [0]
Yes [1]

Q8. Have you ever tried eating lionfish?
No [0]
Yes [1] (skip to Q10)

Q9. Could you tell me why you have not tried lionfish?
[open ended] (skip to Q21)

Q10. Have you eaten lionfish more than once?
[select one]
No [0]
Yes [1]

Q11. Have you ever purchased lionfish?
[select one]
No [0]
Yes [1]

Q12. Where did you first eat lionfish? (frequency)
[Select one]

Home [0]
Restaurant [1]
Sponsored event [2]
Party [3]
Other_____ [open ended response; coded]

Q13. In what year did you first try lionfish?
[Open ended]

Q14. When thinking about the first time you tried Lionfish, were you…
[Select one]

One of the first to try it [0]
You tried it after SOME friends/family tried it [1]
You tried it after MANY friends/family tried it [2]
Were you very reluctant to try it [3]

Q15. How much would you pay for a pound of lionfish at the market?
[open ended amount]

Q16. How much would you pay for a bowl of lionfish ceviche?
[open ended amount]

Q17. How much would you pay for a lionfish fillet with a plate of rice and beans?
[open ended amount]

Q18. If you were offered a free sample of lionfish at the market, would you try it?
[select one]
No [0]
Yes [1]
Undecided [2]

Q19.Could you tell me why you would not try lionfish?
[open ended]

Level of Knowledge-

Now I want to ask you a few questions about lionfish…

Q20. How much do you know about lionfish?
[select one]

None [1]
A little bit [2]
Some [3]
Quite a bit [4]
A lot [5]

Q21. I am going to give you 7 statements, please tell me whether you think they are "***True***" *OR "****False***".
[select one]

True [2]
False [0]
Uncertain [1]

Lionfish have always been in Belize's waters (F)
Lionfish are bad for the reefs (T)
Lionfish are moving to new areas (T)
Lionfish can't be handled (F)
People die from lionfish stings (F)
Lionfish threaten Belize's fishing industry (T)
Lionfish meat is safe to eat (T)

Attitudes and Perceptions-

Q22. Please state how much you AGREE or DISAGREE with the following statements about lionfish.
[select one]
Strongly disagree [1]
Somewhat disagree [2]
Undecided [3]
Somewhat agree [4]
Strongly agree [5]

I would purchase lionfish if I knew it had a benefit for the reef…
I like other fish too much to buy lionfish…
Belizeans will never eat lionfish…
I would purchase lionfish if I knew it benefited local fishermen…
Even if lionfish was commonly available I probably wouldn't buy it…
Lionfish is currently too expensive...
I would purchase lionfish if it was regularly available…
I would pay more for a Belizean product than for a similar, but less expensive one from

somewhere else...
I am worried about lionfish…

[if they somewhat or strongly agree] ask the following statement
Q 22a. Since you agreed, could you tell me why you are worried?
[open ended]

Q23. Please state how much you AGREE or DISAGREE with the following statements about your eating habits....
[select one]
Strongly disagree [1]
Somewhat disagree [2]
Undecided [3]
Somewhat agree [4]
Strongly agree [5]

I do not trust new foods… (attitude)
I will eat almost anything...
When considering what food to buy my main consideration is how much it costs… (attitude)
Fish is too expensive… (attitude)
I am curious to try new foods… (attitude)
I like to try new recipes

Information Networks-

Q24. What source of media to you get MOST of your information from?
[select one]

Social media (fb, twitter, etc.) [0]
Radio [1]
TV News [2]
Newspaper [3]
Internet news (other than social media) [4]
Word of mouth [5]
School [6]
Other [open ended response; coded]

Sociodemographic-

Finally, I would like to ask you some questions about yourself...

[researcher selects]

Female [0]
Male [1]

Q25. What is your age?
[Allow range]
18-150

Q26. What is your cultural identity?
[Select one]
Mestizo/Latino [0]
Creole [1]
Mayan [2]
Garifuna [3]
East Indian [4]
Caucasian [5]
Other [open ended; coded]

Q27. What is the name of your community?
[open ended response; coded]

Q28. What district is that in?
[open ended response; coded]
Corozal [0]
Orange Walk [1]
Belize [2]
Cayo [3]
Stann Creek [4]
Toledo [5]

Q29. Please tell me YES or NO if you have the following in your house...
No [0]
Yes [1]

[select all that apply]
1 Vehicle (inc. motorcycle)
2 Vehicles (inc. motorcycle)
3 Vehicles (inc. motorcycle)
A bicycle
A cell phone
TV
Microwave
Refrigerator
Washing machine
Computer

I am going to ask you a few questions about your house...

Q30. What is your roof made of
[Select one]
metal [3]
concrete [2]
thatch [1]
other

Q 31. What are your walls made of
[Select one]
concrete [2]
wood [1]
other

Q32. What are your floors made of
[Select one]
concrete [3]
wood [2]
dirt [1]
other
What was the “other” you mentioned?

Q33. What is your occupation?
[open ended response; coded]

Q34. What is the primary job that provides income for your household?
[open ended response; coded]

Q35. What is the highest level of formal education you have achieved?
[choose one]

Pre school [0]
Primary school [1]
Secondary/high school [2]
6th form/Jr. college/ associate's degree [3]
Bachelors [4]
Masters/Ph.D. degree [5]

APPENDIX D

Chapter 3 supplementary tables

Appendix Table D1: Analyses using Mann-Whitney U tests comparing number of lionfish killed based on top motivation for motivations ranked first at least four times.

Motivation	Ranked motivation first # lionfish killed mean rank	Did not rank motivation first # lionfish killed mean rank	Analysis Mann-Whitney U	 *p*-value
To help protect Florida's reefs	*n* = 77 61.82	*n* = 61 79.20	1757	.011
They taste good	*n* = 18 69.42	*n* = 120 69.51	1079	.992
It's fun to hunt for them	*n* = 23 75.41	*n* = 115 68.32	1187	.436
To keep them from eating other fish that I like to hunt	*n* = 9 82.22	*n* = 129 68.61	466	.322
To make money from selling them	*n* = 4 134.00	*n* = 134 67.57	10	.001 η^2 = .078

Appendix Table D2: Analyses using Mann-Whitney U tests comparing number of lionfish killed based on the existence of each type of social tie. A * indicates a *p*-value of less than .05. For comparisons in which the shape of the distributions were dissimilar, mean ranks are reported.

Tie type	At least one tie Median # lionfish killed	 IQR	No tie Median # lionfish killed	 IQR	Analysis Mann-Whitney U	 *p*-value
This is one of the primary people I dive with	*n* = 65 50.0	22.5-250.0	*n* = 41 125.0	32.5-400	1134	.196
I spend time with this person outside of diving together	*n* = 56 55.0	26.3-275.0	*n* = 50 100.0	30.0-400.0	1284	.462
I have a close relationship with this person	*n* = 52 50.0	30.0-300.0	*n* = 54 100.0	30.0-325.0	1265	.377
	Mean rank		Mean rank			

I helped this person when they first began lionfish hunting	*n* = 30 60.70	*n* = 76 50.66	1356	.129
This person helped me when I first began lionfish hunting	*n* = 31 50.63	*n* = 75 54.69	1074	.536
I go diving on this person's boat	*n* = 34 51.44	*n* = 72 54.47	1154	.635
This person comes diving on my boat	*n* = 30 54.77	*n* = 76 53.00	1178	.789
I share private numbers (GPS locations) with this person	*n* = 24 62.29	*n* = 82 50.93	1195	.110
This person shares private numbers (GPS locations) with me	*n* = 24 62.98	*n* = 82 50.73	1212	.085
This person helps me sell my lionfish*	*n* = 8 84.13	*n* = 98 51.00	637	.003* η^2 = 0.081

APPENDIX E

Online questionnaire sent to Florida lionfish divers, with an example social network map

Hello,

Thank you for your interest in participating in this survey. My name is Kaylin Clements and I am a doctoral student from Colorado State University in the department of Human Dimensions of Natural Resources. I am conducting a research study on the experiences and social networks of divers and spearfishers involved in lionfish removal in Florida.

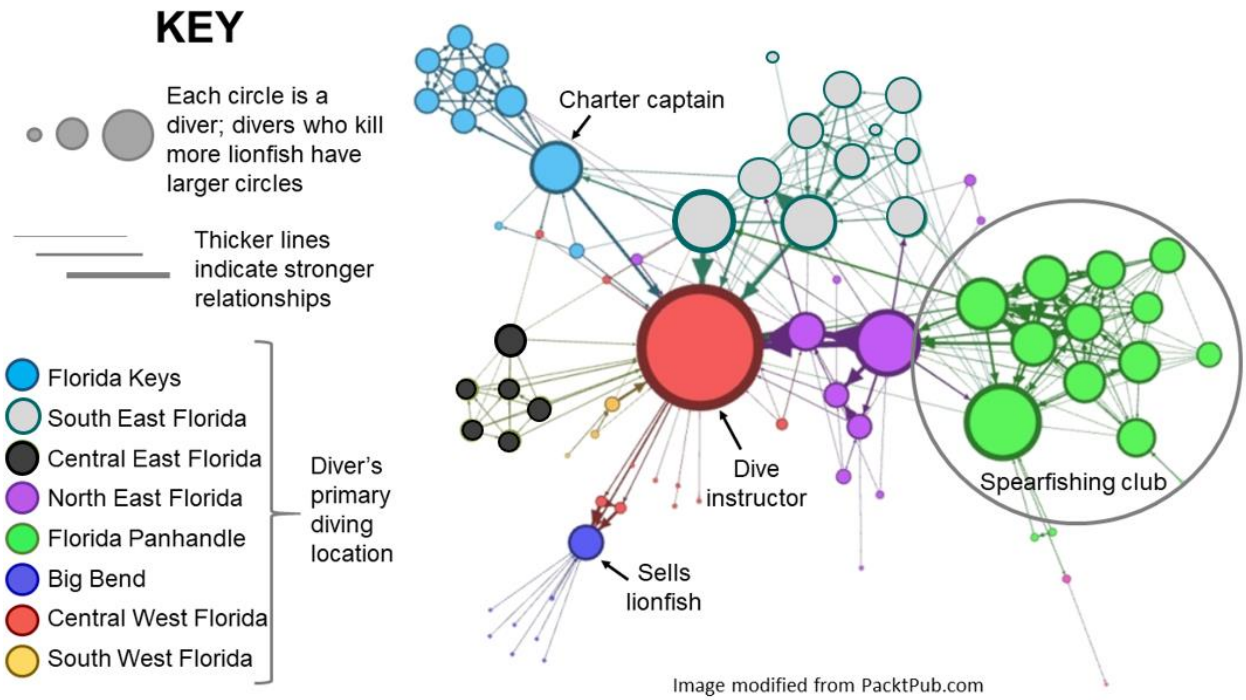
I invite you to contribute to this research by completing an online survey. Participation will take 25-35 minutes. You must be 18 years or older to participate in this survey. Your participation is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participation at any time without penalty.

To thank you for your time, **your name will be entered into a raffle drawing provided by the Fish and Wildlife Foundation of Florida.** Multiple prizes are available, including an Engel Backpack Cooler, Engel Silipints, and Reef Rangers nalgenes.

The first part of the survey will focus on your experiences as a lionfish hunter. The second part will ask you questions about your lionfish hunting or diving network and will request that you provide referrals and email addresses of fellow divers to the degree that you feel comfortable and are able.

Why do I need to give names of my contacts? What will be done with this data? My research seeks to conduct a social network analysis, in which we investigate how relationships and groups of people throughout Florida influence removal of lionfish. To do so requires people's names, including your own.

You and other participants' contributions will help me develop social network maps such as the fictional one below.



Your responses will remain completely anonymous. Your name, contact information, and any other personally identifying information will never in any way be released or associated with your responses in reporting of the data. Recommendations you provide for additional survey participants will not be connected to you without your permission.

In addition, there are no known risks associated with your participation in this study and no benefits outside of the raffle prize described above. Keep in mind that, in accordance with federal regulations in the United States, the Colorado State University Institutional Review Board has reviewed and approved this study.

If you have any questions about this study, please contact me at (305) 546-0151. If you have questions about your rights as a participant in this research, you may contact the Colorado State University Institutional Review Board Administrator at (970) 491-1553 or RICRO_IRB@mail.colostate.edu.

To indicate your consent to participate in this research and to continue on to the survey, please continue to the next page.

Your diving experience: The following questions are focused on your experience with diving in saltwater and spearing lionfish.

1 Have you spearfished in the last two years?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Have you spearfished in the last two years? = No

Display This Question:
If Have you spearfished in the last two years? = Yes

2 What year did you start diving (in saltwater)?

Dropdown list of options for years 1932 - 2021

3 Which of the following best describes you?

- ○ Free diver
- ○ Scuba diver
- ○ Spearfisher

Display This Question:

If Which of the following best describes you? = Scuba diver

4S Of the following, which is your highest level of dive certification?

- ○ Open water or rescue diver
- ○ Advanced open water
- ○ Master scuba diver
- ○ Divemaster
- ○ Professional (above divemaster)

Display This Question:

If Which of the following best describes you? = Scuba diver

5S How many dive specialty certifications have you completed?

Dropdown list of options from 0-20

Display This Question:

If Which of the following best describes you? = Scuba diver

6S When I participate in scuba diving I feel like:

- ○ a beginner. I don't really feel like I am part of the scuba diving scene.
- ○ an occasional or irregular participant. Sometimes it is fun, entertaining or rewarding to go scuba diving.
- ○ a habitual and regular participant in the activity of scuba diving.
- ○ an insider to scuba diving. Scuba diving is an important part of who I am.

Display This Question:

If Which of the following best describes you? = Scuba diver

7S During a scuba diving experience I can best be described as:

- having very little understanding of scuba diving. I am often unsure about how to do certain things when I go scuba diving.
- having some understanding of scuba diving, but still in the process of learning more about it. I am becoming more familiar and comfortable with scuba diving.
- being comfortable with scuba diving. I have a good understanding of what I can do while scuba diving, and how to do it.
- a knowledgeable expert in scuba diving. I encourage, teach and enhance opportunities for others who are interested in scuba diving.

Display This Question:

If Which of the following best describes you? = Scuba diver

8S My relationships with other scuba divers are:

- not established. I really don't know any other scuba divers.
- very limited. I know some other scuba divers by sight and sometimes talk with them, but I don't know their names.
- one of familiarity. I know the names of other scuba divers, and often speak with them.
- close. I have personal and close relationships with other scuba divers.

Display This Question:

If Which of the following best describes you? = Scuba diver

9S My commitment to scuba diving is:

- very slight. I have very little connection to scuba diving. I may or may not continue to scuba dive in the future.
- moderate. I will continue to go scuba diving as long as it provides the benefits I want.
- fairly strong. I have a sense of being a member of the activity, and it is likely that I will continue to scuba dive for a long time.
- very strong. I am totally committed to scuba diving. I encourage others to go scuba diving, and seek to ensure the activity continues into the future.

Display This Question:

If Which of the following best describes you? = Spearfisher

4SP Do you typically scuba dive or free dive when you spearfish?

- Scuba dive
- Free dive

Display This Question:

If Do you typically scuba dive or free dive when you spearfish? = Scuba dive

5SP Of the following, which is your highest level of dive certification?

- ○ Open water or rescue diver
- ○ Advanced open water
- ○ Master scuba diver
- ○ Divemaster
- ○ Professional (above divemaster)

Display This Question:

If Do you typically scuba dive or free dive when you spearfish? = Free dive

6SP How many minutes can you hold your breath while diving?

Dropdown list of options from 1-25

Display This Question:

If Which of the following best describes you? = Spearfisher

7SP When I participate in spearfishing I feel like:

- ○ an outsider. I don't really feel like I am part of the spearfishing scene
- ○ an occasional or irregular participant. Sometimes it is fun, entertaining or rewarding to go spearfishing.
- ○ a habitual and regular participant in the activity of spearfishing.
- ○ an insider to spearfishing. Spearfishing is an important part of who I am.

Display This Question:

If Which of the following best describes you? = Spearfisher

8SP During a spearfishing experience I can best be described as:

- ○ having very little understanding of spearfishing. I am often unsure about how to do certain things when I go spearfishing.
- ○ having some understanding of spearfishing, but still in the process of learning more about it. I am becoming more familiar and comfortable with spearfishing.
- ○ being comfortable with spearfishing. I have a good understanding of what I can do while spearfishing, and how to do it.
- ○ a knowledgeable expert in spearfishing. I encourage, teach and enhance opportunities for others who are interested in spearfishing.

Display This Question:

If Which of the following best describes you? = Spearfisher

9SP My relationships with other spearfishers are:

- ○ not established. I really don't know any other spearfishers.
- ○ very limited. I know some other spearfishers by sight and sometimes talk with them, but I don't know their names.
- ○ one of familiarity. I know the names of other spearfishers, and often speak with them.
- ○ close. I have personal and close relationships with other spearfishers.

Display This Question:

If Which of the following best describes you? = Spearfisher

10SP My commitment to spearfishing is:

- ○ very slight. I have very little connection to spearfishing. I may or may not continue to spearfish in the future.
- ○ moderate. I will continue to go spearfishing as long as it provides the benefits I want.
- ○ fairly strong. I have a sense of being a member of the activity, and it is likely that I will continue to spearfish for a long time.
- ○ very strong. I am totally committed to spearfishing. I encourage others to go spearfishing, and seek to ensure the activity continues into the future.

Display This Question:

If Which of the following best describes you? = Free diver

4F How many minutes can you hold your breath while diving?

Dropdown list of options from 1-25

Display This Question:

If Which of the following best describes you? = Free diver

5F When I participate in free diving I feel like:

- ○ a beginner. I don't really feel like I am part of the free diving scene.
- ○ an occasional or irregular participant. Sometimes it is fun, entertaining or rewarding to go free diving.
- ○ a habitual and regular participant in the activity of free diving.
- ○ an insider to free diving. Free diving is an important part of who I am.

Display This Question:

If Which of the following best describes you? = Free diver

6F During a free diving experience I can best be described as:

- ○ having very little understanding of free diving. I am often unsure about how to do certain things when I go free diving.
- ○ having some understanding of free diving, but still in the process of learning more about it. I am becoming more familiar and comfortable with free diving.
- ○ being comfortable with free diving. I have a good understanding of what I can do while free diving, and how to do it.
- ○ a knowledgeable expert in free diving. I encourage, teach and enhance opportunities for others who are interested in free diving.

Display This Question:

If Which of the following best describes you? = Free diver

7F My relationships with other free divers are:

- ○ not established. I really don't know any other free divers.
- ○ very limited. I know some other free divers by sight and sometimes talk with them, but I don't know their names.
- ○ one of familiarity. I know the names of other free divers, and often speak with them.
- ○ close. I have personal and close relationships with other free divers.

Display This Question:

If Which of the following best describes you? = Free diver

8F My commitment to free diving is:

- ○ very slight. I have very little connection to free diving. I may or may not continue to free dive in the future.
- ○ moderate. I will continue to go free diving as long as it provides the benefits I want.
- ○ fairly strong. I have a sense of being a member of the activity, and it is likely that I will continue to free dive for a long time.
- ○ very strong. I am totally committed to free diving. I encourage others to go free diving, and seek to ensure the activity continues into the future.

---

9 What is the deepest you typically dive?

Dropdown list with the following options:

- ○ 0-15 feet
- ○ 16-30 feet
- ○ 31-60 feet
- ○ 61-90 feet
- ○ 91-130 feet
- ○ 131-160 feet
- ○ 161-190 feet
- ○ 191-220 feet
- ○ 221-250 feet
- ○ 251-280 feet
- ○ 281-310 feet
- ○ 311+

9A Approximately how many dives do you typically go on in a year?

	0	100	200	300	400	500
Dives per year						

10 When you dive, do you normally use your own boat?

- ○ Yes
- ○ No
- ○ Not Applicable

Skip To: 11 If When you dive, do you normally use your own boat? = Yes

Display This Question:

If When you dive, do you normally use your own boat? = No

Or When you dive, do you normally use your own boat? = Not Applicable

10A Whose boat are you most likely to go out on?

- ○ A charter
- ○ Individual/friend with a boat
- ○ Borrow a boat from an individual/friend
- ○ Rent a boat
- ○ I dive from shore
- ○ Other: (if other, please write in a response)

_____

11 Do you have your own diving equipment?

- ○ I have all of my own equipment
- ○ I have some of my own equipment
- ○ I have none of my own equipment

11A Do you have your own spearing tool?

- ○ Yes
- ○ No

12A For the year *before* the COVID-19 pandemic began (between March 1st 2019 and March 1st 2020), which of the following activities did you participate in, if any? Check all that apply.

- ☐ Lionfish tournament, roundup, or derby
- ☐ FWC's Lionfish Challenge
- ☐ Charter reimbursement program
- ☐ Lionfish festival
- ☐ Lionfish cookoff or tasting
- ☐ Lionfish research
- ☐ Commercial sale of lionfish
- ☐ A volunteer program related to lionfish
- ☐ None
- ☐ Other (if other, please write in a response)

_____

12B Since the COVID-19 pandemic began, have you gone diving *more* or *less*?

- ○ Far less
- ○ Moderately less
- ○ Slightly less
- ○ Hasn't changed
- ○ Slightly more
- ○ Moderately more
- ○ Far more

---

14 **Before** the COVID-19 pandemic began, how often did you see lionfish while diving?

- ○ Never
- ○ Rarely
- ○ Occasionally
- ○ Sometimes
- ○ Frequently
- ○ Usually
- ○ Almost always

14A **Since** the COVID-19 pandemic began, how often do you see lionfish while diving?

- Never
- Rarely
- Occasionally
- Sometimes
- Frequently
- Usually
- Almost always

Display This Question:

If Before the COVID-19 pandemic began, how often did you see lionfish while diving? != Never

15 When you do see lionfish while diving, how often do you kill them?

- Never
- Rarely
- Occasionally
- Sometimes
- Frequently
- Usually
- Almost always

Display This Question:

If Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

And When you do see lionfish while diving, how often do you kill them? "Never" is not selected

16 After you've killed a lionfish what do you do most often with it? Please select all that apply.

- ☐ Leave the lionfish in the water after I've killed it
- ☐ Take it home to eat
- ☐ Share it with somebody
- ☐ Give it to someone to sell
- ☐ Sell it
- ☐ Donate it
- ☐ Turn it in for a tournament/competition
- ☐ Other: (if other, please write in a response) _____

16A What type of gear do you typically use to target lionfish?

- ○ Polespear
- ○ Hawaiian sling
- ○ Speargun
- ○ Other: (if other, please write in a response) _____

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

17 In what year did you kill your first lionfish?

Dropdown list of options from 2000-2021

Display This Question:

If Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

And When you do see lionfish while diving, how often do you kill them? "Never" is not selected

18 **(Required question)* For the year *before* the COVID-19 pandemic began (between March 1st 2019 and March 1st 2020), approximately how many lionfish in total did you **personally** kill in Florida? Note: "Personally" means as an individual, so if you've collected lionfish on a team or in a group, please count only the ones you collected yourself. We understand it may be difficult to remember the exact number of fish so please simply provide your best estimate.

_____

Display This Question:

If Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

And When you do see lionfish while diving, how often do you kill them? "Never" is not selected

18A **(Required question)* Considering the lionfish you killed in Florida in the year *before* the COVID-19 pandemic began (between March 1st 2019 and March 1st 2020), how many did you collect **for a tournament or competition**?

_____

Display This Question:

If Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

And When you do see lionfish while diving, how often do you kill them? "Never" is not selected

19 **(Required question)* For the year *before* the COVID-19 pandemic began (between March 1st 2019 and March 1st 2020), approximately how many lionfish did you personally **sell** in Florida? Note: We understand it may be difficult to remember the exact number of fish so please simply provide your best estimate.

_____

Display This Question:

If Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

And When you do see lionfish while diving, how often do you kill them? "Never" is not selected

20 At what depth do you typically kill the most lionfish?

Dropdown list of the following options:

- ○ 0-15 feet
- ○ 16-30 feet
- ○ 31-60 feet
- ○ 61-90 feet
- ○ 91-130 feet
- ○ 131-160 feet
- ○ 161-190 feet
- ○ 191-220 feet
- ○ 221-250 feet
- ○ 251-280 feet
- ○ 281-310 feet
- ○ 311+
- ○ Not applicable

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

21 In which region off Florida's coast do you typically hunt for lionfish? Please try to choose the region that aligns most with the body of water where you dive as opposed to where you put in. For example, if you put in near Miami but boat down to the Keys to dive, then choose the Keys.

- ○ Panhandle
- ○ Big Bend
- ○ Central West
- ○ Southwest
- ○ The Keys
- ○ South East
- ○ Central East
- ○ Northeast
- ○ Not applicable

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

Lionfish hunting: The following questions are focused on your level of involvement with lionfish removal. Here, the term "lionfish hunting" will refer to any diving in which you kill lionfish, even if it is not always the primary goal.

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

22 When I hunt for lionfish I feel like:

- a beginner. I don't really feel like I am part of the lionfish hunting scene.
- an occasional or irregular participant.
- a habitual and regular participant in the activity of lionfish diving.
- an insider to lionfish diving. Lionfish diving is an important part of who I am.

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

23 During a lionfish hunting experience I can best be described as:

- having very little understanding of lionfish hunting. I am often unsure about how to do certain things when I go lionfish hunting.
- having some understanding of lionfish hunting, but still in the process of learning more about it. I am becoming more familiar and comfortable with lionfish hunting.
- being comfortable with lionfish hunting. I have a good understanding of what I can do while lionfish hunting, and how to do it.
- a knowledgeable expert in lionfish hunting.
- a knowledgeable expert AND I encourage, teach or enhance opportunities for others who are interested in hunting for lionfish.

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

24 My relationships with other lionfish hunters are:

- ○ not established. I really don't know any other lionfish hunters.
- ○ very limited. I know some other lionfish hunters by sight and sometimes talk with them, but I don't know their names.
- ○ one of familiarity. I know the names of other lionfish hunters, and often speak with them.
- ○ close. I have personal and close relationships with other lionfish hunters.

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

25 My commitment to lionfish hunting is:

- ○ very slight. I have very little connection to lionfish hunting. I may or may not continue to hunt lionfish in the future.
- ○ moderate. I will continue to go lionfish hunting as long as it provides the benefits I want.
- ○ fairly strong. I have a sense of being a member of the activity, and it is likely that I will continue to hunt lionfish for a long time.
- ○ very strong. I am totally committed to hunting lionfish. I encourage others to go lionfish hunting, and seek to ensure the activity continues into the future.

Display This Question:

If Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

And When you do see lionfish while diving, how often do you kill them? "Never" is not selected

Motivations: The purpose of the following questions is to get to know your motivations for hunting lionfish and/or selling lionfish.

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

26A Why do you choose to hunt lionfish? Please select all that apply.

- ☐ It's fun to hunt for them
- ☐ To help protect Florida's reefs
- ☐ They taste good
- ☐ It is more sustainable for fisheries to harvest lionfish than other fish
- ☐ To make money from selling them
- ☐ To win prizes
- ☐ Camaraderie with other lionfish hunters
- ☐ I like to compete with other lionfish hunters
- ☐ To feel connected with my diving community
- ☐ To keep them from eating other fish that I like to hunt
- ☐ It's easy to spear lionfish in comparison to other fish
- ☐ When other fish are out of season, I can still hunt for lionfish
- ☐ Other (if other, please write in a response)

_____

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

26B Please rank the reasons you choose to hunt lionfish. Rank each motivation you selected by **clicking and dragging**. Place them in **order from strongest motivation at the top to least strong motivation at the bottom.**

Previously selected choices are listed to be moved into rank order

---

Display This Question:

If When you do see lionfish while diving, how often do you kill them? "Never" is not selected

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

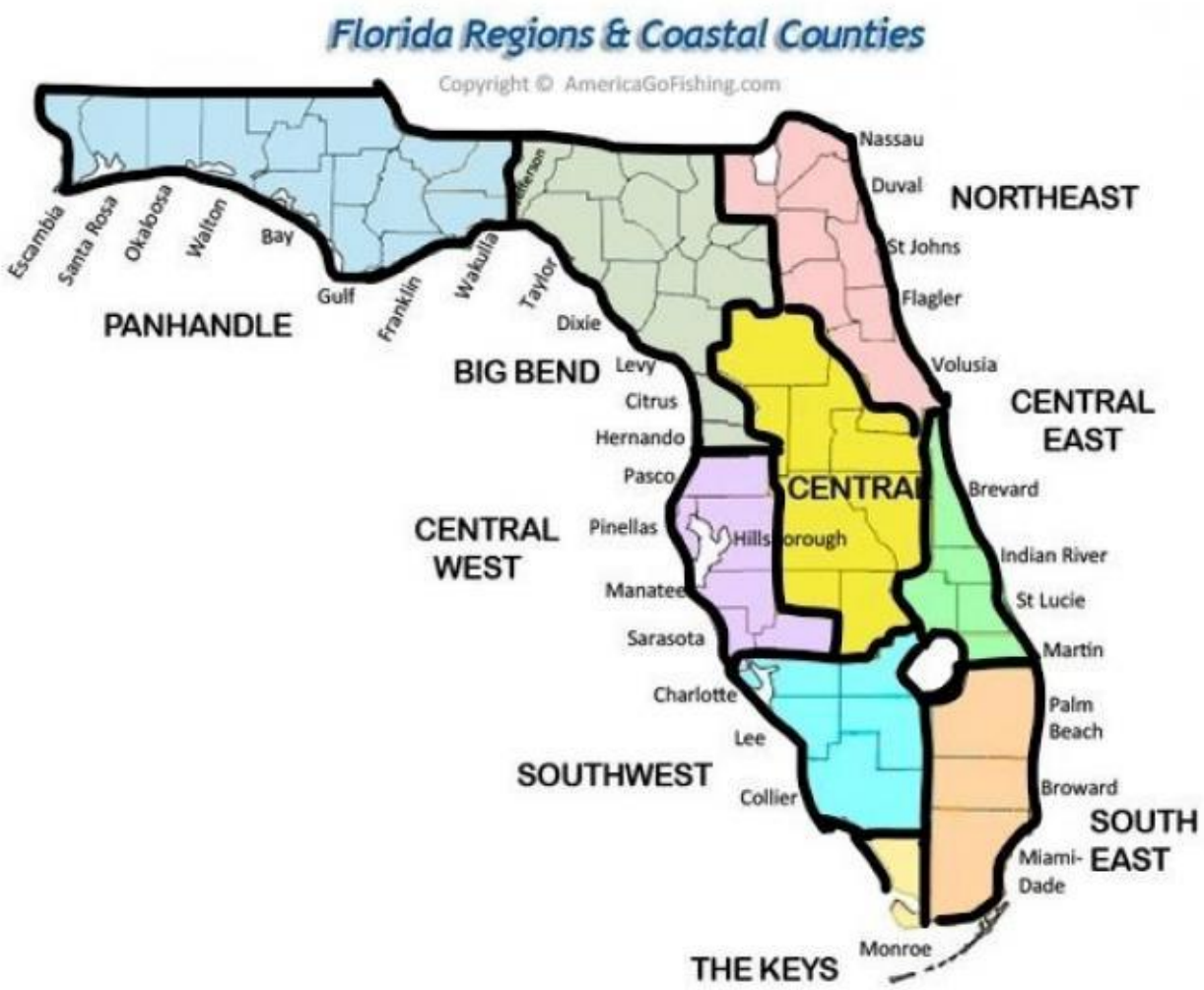
26C Since the COVID-19 pandemic began, have you killed more or less lionfish?

- ○ Far less
- ○ Moderately less
- ○ Slightly less
- ○ Hasn't changed
- ○ Slightly more
- ○ Moderately more
- ○ Far more

Display This Question:

If Before the COVID-19 pandemic began, how often did you see lionfish while diving? = Never

14N In which region off Florida's coast do you typically dive? Please try to choose the region that aligns most with the body of water where you dive as opposed to where you put in. For example, if you put in near Miami but boat down to the Keys to dive, then choose the Keys.



- ○ Panhandle
- ○ Big Bend
- ○ Central West
- ○ Southwest
- ○ The Keys
- ○ South East
- ○ Central East
- ○ Northeast

Display This Question:

If When you do see lionfish while diving, how often do you kill them? = Never

And Before the COVID-19 pandemic began, how often did you see lionfish while diving? != Never

Why don't you spear lionfish when you see them?

_____

_____

_____

_____

_____

For the following statements, I am interested in your opinions. There is no right or wrong answer. Please choose to what extent you agree with the following statements from strongly disagree to strongly agree.

---

27 I feel a personal obligation to help control the lionfish population in Florida

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

---

28 When I see a lionfish but don't kill it, I feel regret

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

---

29 I feel it is my duty to hunt lionfish

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

---

30 My diving friends would want me to hunt lionfish

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

---

31 Other divers would expect me to do my part to protect the reef.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

---

32 Other divers would disapprove of only targeting large lionfish

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

---

33 For me to go hunting for lionfish when I want to (weather permitting) is

- ○ Extremely difficult
- ○ Difficult
- ○ Somewhat difficult
- ○ Moderate
- ○ Somewhat easy
- ○ Easy
- ○ Extremely easy

---

34 Whether or not I go hunting for lionfish when I want to (weather permitting) is completely up to me.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

---

35 I have access to everything I need in order to go hunting for lionfish.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree

Display This Question:

If Before the COVID-19 pandemic began, how often did you see lionfish while diving? "Never" is not selected

And When you do see lionfish while diving, how often do you kill them? "Never" is not selected

36 Do you ever sell lionfish?

- ○ Yes
- ○ No
- ○ I used to but I don't anymore

Display This Question:

If Do you ever sell lionfish? = Yes

36A Why do you choose to sell lionfish? Please select all that apply.

- [ ] I sell lionfish to help pay for my diving trips.
- [ ] Profits from selling lionfish is an important part of my income.
- [ ] I like to sell lionfish so more people can try it.
- [ ] The lionfish market is an important strategy for controlling the invasion.
- [ ] I value contributing to a sustainable seafood market.
- [ ] Buyers ask me for lionfish.
- [ ] It is meaningful for me to contribute to the excitement around lionfish.
- [ ] Other (if other, please write in a response)

_____

Display This Question:

If Do you ever sell lionfish? = Yes

36B Please rank the reasons you choose to sell lionfish. Click on each of the motivations and drag them to the rank you choose, with your primary motivation at the top and your lowest rank motivation at the bottom.

Previously selected choices are listed to be moved into rank order

Display This Question:

If Do you ever sell lionfish? = No

Or Do you ever sell lionfish? = I used to but I don't anymore

36No What are the TOP reason(s) you choose not to sell lionfish? Please select all that apply.

- [ ] I just do it for fun
- [ ] Hunting lionfish for money would make it less enjoyable
- [ ] I don't catch enough to sell
- [ ] I don't catch enough LARGE lionfish to sell
- [ ] I wouldn’t get paid enough for lionfish
- [ ] It’s a hassle to sell lionfish
- [ ] I don’t have someone to sell it to
- [ ] I don’t have access to a boat
- [ ] I don’t know how to sell lionfish
- [ ] There isn’t a market for lionfish in my area
- [ ] I don't have a license to sell lionfish
- [ ] Other (if other, please write in a response)

_____

Display This Question:

If Do you ever sell lionfish? = Yes

36C Who do you sell lionfish to most often?

- ○ Halperns' Steak and Seafood
- ○ A wholesaler (but not Halperns)
- ○ A local restaurant
- ○ I give my fish to someone and he/she sells them
- ○ I donate my fish to a restaurant
- ○ Prefer not to say
- ○ Other (if other, please write in a response)

_____

Display This Question:

If Do you ever sell lionfish? = Yes

36D Since the COVID-19 pandemic began, have you sold more or less lionfish?

- ○ Far less
- ○ Moderately less
- ○ Slightly less
- ○ Hasn't changed
- ○ Slightly more
- ○ Moderately more
- ○ Far more

The next questions relate to people who are part of the spearfishing or dive communities. Think about all the people you are connected to and know. Looking at the list below, **LIST up to 10 people who fit any of these categories.**

A person who:

- you dive with
- you are friends with and they dive for lionfish but not necessarily with you
- compete with you in tournaments
- give you their lionfish
- you give lionfish to
- you sell lionfish to
- communicate with you frequently about the topic of lionfish
- you share numbers (GPS locations) with
- share numbers with you
- take you out on their boat or vice versa
- share equipment with you

In order for us to do proper network analysis, we do need you to **provide full names and email address below as often as you can. If you do not know the person's email, then please provide their phone number.**

Confidentiality. We will not share your name or answers when we reach out to your contacts but will say that they were referred to us by one of their acquaintances. While we need names initially to create the network, once all data is collected, names will be removed from the survey and replaced with participant numbers. Your name will not ever be associated with the network images or analysis.

Please list their first and last name and avoid using nicknames.

---

40 Do you know anyone who fits any of the categories above?

- ○ Yes
- ○ No

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-1 List up to 10 people who fit any of these categories.

A person who:

- you dive with
- you are friends with and they dive for lionfish but not necessarily with you
- compete with you in tournaments
- give you their lionfish
- you give lionfish to
- you sell lionfish to
- communicate with you frequently about the topic of lionfish
- you share numbers (GPS locations) with
- share numbers with you
- take you out on their boat or vice versa
- share equipment with you

Person 1

○ First name _____

○ Last name _____

○ Email _____

○ Phone number (if don't know email) _____

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-2 Person 2

- First name _____
- Last name _____
- Email _____
- Phone number (if don't know email) _____

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-3 Person 3

- First name _____
- Last name _____
- Email _____
- Phone number (if don't know email) _____

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-4 Person 4

- First name _____
- Last name _____
- Email _____
- Phone number (if don't know email) _____

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-5 Person 5

- First name _____
- Last name _____
- Email _____
- Phone number (if don't know email) _____

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-6 Person 6

- First name _____
- Last name _____
- Email _____
- Phone number (if don't know email) _____

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-7 Person 7

- First name _____
- Last name _____
- Email _____
- Phone number (if don't know email) _____

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-8 Person 8

- First name _____
- Last name _____
- Email _____
- Phone number (if don't know email) _____

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-9 Person 9

- First name _____
- Last name _____
- Email _____
- Phone number (if don't know email) _____

Display This Question:

If Do you know anyone who fits any of the categories above? = Yes

40-10 Person 10

- First name _____
- Last name _____
- Email _____
- Phone number (if don't know email) _____

Display This Question:

If If List up to 10 people who fit any of these categories. A person who: you dive with you are frien... First name Is Not Empty

Or Or List up to 10 people who fit any of these categories. A person who: you dive with you are frien... Last name Is Not Empty

For each person that you listed, how would you describe your relationship with him/her? Please select all that apply. If you choose "other", please write in a response.

Display This Question:

If If List up to 10 people who fit any of these categories. A person who: you dive with you are frien... First name Is Not Empty

Or Or List up to 10 people who fit any of these categories. A person who: you dive with you are frien... Last name Is Not Empty

42-1 *Person 1 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving together
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If chose "I share private numbers (GPS locations) with this person"

42-1 How many of your private numbers do you share with *Person 1 Name*?

- ○ Some of my numbers
- ○ A lot of my numbers
- ○ Almost all my numbers

Display This Question:

If If Person 2 First name Is Not Empty

Or Or Person 2 Last name Is Not Empty

42-2 *Person 2 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving together
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If chose "I share private numbers (GPS locations) with this person"

42-2 How many of your private numbers do you share with *Person 2 Name*

- ○ Some of my numbers
- ○ A lot of my numbers
- ○ Almost all my numbers

Display This Question:

If If Person 3 First name Is Not Empty

Or Or Person 3 Last name Is Not Empty

42-3 *Person 3 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving together
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If chose "I share private numbers (GPS locations) with this person"

42-3 How many of your private numbers do you share with *Person 3 Name*?

- ○ Some of my numbers
- ○ A lot of my numbers
- ○ Almost all my numbers

Display This Question:

If If Person 4 First name Is Not Empty

Or Or Person 4 Last name Is Not Empty

42-4 *Person 4 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving together
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If If chose "I share private numbers (GPS locations) with this person"

42-4 How many of your private numbers do you share with *Person 4 Name*?

- ○ *Some of my numbers*
- ○ A lot of my numbers
- ○ Almost all my numbers

Display This Question:

If If Person 5 First name Is Not Empty

Or Or Person 5 Last name Is Not Empty

42-5 *Person 5 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving together
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If If chose "I share private numbers (GPS locations) with this person"

42-5 How many of your private numbers do you share with *Person 5 Name*?

- ○ Some of my numbers
- ○ A lot of my numbers
- ○ Almost all my numbers

Display This Question:

If If Person 6 First name Is Not Empty

Or Or Person 6 Last name Is Not Empty

42-6 *Person 6 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving together
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If If chose "I share private numbers (GPS locations) with this person"

42-6 How many of your private numbers do you share with *Person 6 Name*?

- ○ Some of my numbers
- ○ A lot of my numbers
- ○ Almost all my numbers

Display This Question:

If If Person 7 First name Is Not Empty

Or Or Person 7 Last name Is Not Empty

42-7 *Person 7 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving together
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If chose "I share private numbers (GPS locations) with this person"

42-7 How many of your private numbers do you share with *Person 7 Name*?

- ○ Some of my numbers
- ○ A lot of my numbers
- ○ Almost all my numbers

Display This Question:

If If Person 8 First name Is Not Empty

Or Or Person 8 Last name Is Not Empty

42-8 *Person 8 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving together
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If chose "I share private numbers (GPS locations) with this person"

42-8Numbers How many of your private numbers do you share with *Person 8 Name*?

- ○ Some of my numbers
- ○ A lot of my numbers
- ○ Almost all my numbers

Display This Question:

If If Person 9 First name Is Not Empty

Or Or Person 9 Last name Is Not Empty

42-9 *Person 9 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving together
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If chose "I share private numbers (GPS locations) with this person"

42-9Numbers How many of your private numbers do you share with *Person 9 Name*?

- ○ Some of my numbers
- ○ A lot of my numbers
- ○ Almost all my numbers

Display This Question:

If If Person 10 First name Is Not Empty

Or Or Person 10 Last name Is Not Empty

42-10 *Person 10 Name*

- [ ] This is one of the primary people I dive with
- [ ] I spend time with this person outside of diving
- [ ] I have a close relationship with this person
- [ ] I helped this person when they first began lionfish hunting
- [ ] This person helped me when I first began lionfish hunting
- [ ] I go diving on this person's boat
- [ ] This person comes diving on my boat
- [ ] I share private numbers (GPS locations) with this person
- [ ] This person shares private numbers (GPS locations) with me
- [ ] This person helps me sell my lionfish
- [ ] Other _____

Display This Question:

If chose "I share private numbers (GPS locations) with this person"

42-10Numbers How many of your private numbers do you share with *Person 10 Name*?

- ○ Some of my numbers
- ○ A lot of my numbers
- ○ Almost all my numbers

This social network analysis requires people's names in order to investigate how relationships among divers in Florida influence lionfish removal. While your name is needed simply to identify you when other respondents mention your name, once all data is collected, names will be removed from the survey and replaced with participant numbers. Your name will not ever be associated with the network images or analysis.

What is your first and last name?

- ○ First _____
- ○ Last _____

---

43 In which state do you currently reside?

*Dropdown list of U.S. states as well as option "*I do not reside in the United States"

Display This Question:

If 50 States, D.C. and Puerto Rico = Florida

44 In which county do you currently reside?

*Dropdown list of Florida counties as well as option "*Prefer not to say"

---

45 Have you ever had a Saltwater Products License (SPL)?

- ○ Yes
- ○ No
- ○ Prefer not to say
- ○ I don't know what a Saltwater Products License is

---

46 Are you affiliated with any diving or fishing clubs? If so, what is the name of the club?

_____

---

47 Do you normally use a specific charter or dive shop? If so, please name the charter or dive shop you typically use.

_____

---

48 What is your gender?

- ○ Male
- ○ Female
- ○ Non-binary / third gender
- ○ Prefer not to say

---

49 What year were you born?

Dropdown list of options from 1910-2004

---

50 What is the highest level of school you have completed or the highest degree you have received?

- ○ Less than high school degree
- ○ High school graduate (high school diploma or equivalent including GED)
- ○ Some college but no degree
- ○ Associate degree in college (2-year)
- ○ Bachelor's degree in college (4-year)
- ○ Master's degree
- ○ Doctoral degree
- ○ Professional degree (JD, MD)

Display This Question:

If What is the highest level of school you have completed or the highest degree you have received? = Some college but no degree

Or What is the highest level of school you have completed or the highest degree you have received? = Associate degree in college (2-year)

Or What is the highest level of school you have completed or the highest degree you have received? = Bachelor's degree in college (4-year)

Or What is the highest level of school you have completed or the highest degree you have received? = Master's degree

Or What is the highest level of school you have completed or the highest degree you have received? = Doctoral degree

Or What is the highest level of school you have completed or the highest degree you have received? = Professional degree (JD, MD)

51 What was your main subject of study?

_____

52 Have you ever served on active duty in the US Armed Forces?

- ○ Yes
- ○ No

53 What ethnicity do you identify as?

- ○ Asian
- ○ Black or African American
- ○ Hispanic/Latino/Latinx
- ○ Native American or Alaska Native
- ○ Native Hawaiian or Pacific Islander
- ○ White
- ○ Two or more
- ○ Other _____
- ○ Prefer not to answer

54 In order to be included in the raffle drawing, please provide your preferred email and mailing address so that we can inform you if you win and send you the prize:

- ○ Email _____
- ○ Mailing address: _____

55 Is there anything else you would like to share with us about your experiences regarding lionfish?

_____

_____

_____

_____

_____

APPENDIX F

Semi-structured interview questions for lionfish hunters in Florida

When did you start diving?

When did you start spearfishing?

When did you start spearfishing for lionfish?

What got you into spearing lionfish/why did you start?

Why do you harvest lionfish/what is your motivation for harvesting lionfish?

Why do you think other people harvest lionfish?

How deep do you typically go?

Where do you go? (Locally? Around Florida?)

Do you have an SPL?

Have you ever sold lionfish?

If not why not?

What barriers are there to removing lionfish?

What incentives?

Where do you get information about lionfish from? (specific person? Website? Facebook page?)

For the next several questions, I am trying to get a better understanding of the social networks of divers and their relationships with each other and how that influences removal efforts and the lionfish market in Florida. For each person you list, I will ask you how strong of a relationships you have with that person – weak, medium, or strong. Weak may be someone who is an acquaintance and only see or talk to a couple times a year but don't talk much. Strong would be someone you see and talk to often (maybe once a week) or who you dive with frequently or work with.

Who else do you know who is involved in lionfish removal? (Weak, Medium, Strong?)

What do you think will happen with lionfish in the future?

Would it be okay to contact you with follow-up questions? What is a good email/phone number?